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METAL PROGRESS

METAL PROGRESS

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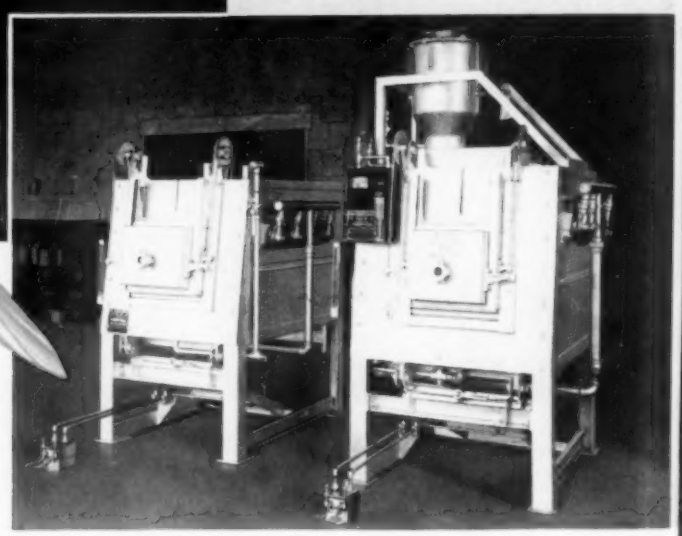
OCTOBER 1939

Again ..AT THE METAL SHOW!.. CHAR-MO

SEE THIS REMARKABLE NEW ATMOSPHERE FURNACE IN ACTION! ...SEE IT TREAT "MOLY" STEEL WITHOUT DECARBURIZATION!

[The Char-Mo furnace is licensed for use under Atmospheric Control Patents owned by The Sentry Company, Foxboro, Mass.]



The Char-Mo furnace is available in both the preheat and superheat type as shown above. The atmosphere gas is generated in a self-contained generator which forms an integral part of the superheat furnace. The preheat furnace is supplied with atmosphere gas from the generator in the superheat furnace . . . In addition to the horizontal muffle type furnace as shown, the Char-Mo furnace is also available in a vertical muffle or pit type.

● So great has been the interest in the Char-Mo furnace, first shown at last year's Metal Show, that it again will be shown in operation at this year's show in Chicago. If you have not seen this outstanding furnace in operation don't miss this opportunity of seeing it.

You will be able to see for yourself the ease, simplicity, and certainty with which molybdenum alloy and other steels—both high speed and carbon—are heat treated without decarburization and without the use of borax or other protective coatings. There is no fuss, no bother, no worry about those expensive tools of yours when treated in the Char-Mo furnace. Borax or other protective coatings are eliminated by the use of a self-generated atmosphere, the composition and flow of which can be easily and quickly varied to be in equilibrium with all types of steels. Char-Mo atmosphere is a mixture of balanced carbon oxides largely diluted with inert nitrogen and is produced in a generator which is an integral part of the superheat furnace.

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Even if the nature of your work does not require a Char-Mo furnace you are still cordially invited to visit our booth in the gas section. There will be on hand a competent staff of engineers who will be glad to discuss with you any heat treating problem you may have.

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SURFACE SC COMBUSTION

October, 1939 Volume 36, Number 4

Metal Progress

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NATIONAL METAL CONGRESS AND EXPOSITION

CHICAGO OCT. 23 to 27, 1939

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CONSOLIDATED PROGRAM

National Metal Congress

Sunday, Oct. 22, 1939

5:00 P.M. American Welding Society (A.W.S.) President's Reception; Stevens Hotel

Monday, Oct. 23, 1939

9:30 A.M. American Society for Metals (⊕) Simultaneous Technical Sessions; Palmer House
9:30 A.M. A.W.S.; Keynote Address; Session on Government Construction Work; Stevens Hotel
10:00 A.M. American Institute of Mining and Metallurgical Engineers (A.I.M.E.) Institute of Metals Division; Session on Die Casting Alloys; Blackstone Hotel
10:00 A.M. A I.M.E. (Iron and Steel Division); Passivity and Pitting of Stainless Steel; Blackstone Hotel
10:30 A.M. Wire Association (W.A.) Directors' Meeting: Congress Hotel
12:00 M. National Metal Exposition opens; International Amphitheatre
12:00 M. W.A.; Program Committee Luncheon; Congress Hotel
12:15 P.M. A.I.M.E. (Institute of Metals); Executive Committee Luncheon Meeting; Blackstone Hotel
12:15 P.M. A.I.M.E.; Committee on Physical Chemistry of Steelmaking; Luncheon Meeting; Blackstone Hotel
2:00 P.M. ⊕ Technical Session; International Amphitheatre
2:00 P.M. A.I.M.E. (Institute of Metals); Session on Cast Brass and Bronze; Blackstone Hotel
2:00 P.M. A.I.M.E. (Iron and Steel); Session on Magnetic Methods in Research and Control; Blackstone Hotel
2:00 P.M. A.W.S.; (*a*) Industrial Research and (*b*) Production Welding in Light Gage Materials; Stevens Hotel
2:30 P.M. W.A.; Technical Session; Congress Hotel
4:30 P.M. ⊕ Lecture Course, Alloying Elements in Steel; International Amphitheatre
8:00 P.M. ⊕ Lecture Course, Visual Examination of Steels; International Amphitheatre
10:30 P.M. National Metal Exposition closes

Tuesday, Oct. 24, 1939

8:00 A.M. ⊕ Board of Trustees Breakfast; Palmer House
9:30 A.M. ⊕ Simultaneous Technical Sessions; Palmer House
9:30 A.M. A.W.S.; Simultaneous Sessions on Fundamental Research and Machinery Construction; Stevens Hotel
9:30 A.M. W.A. (Steel Division and Non-Ferrous Division); Technical Sessions; Congress Hotel
10:00 A.M. A.I.M.E. (Institute of Metals); Session on Structural Metallography; Blackstone Hotel
10:00 A.M. A.I.M.E. (Iron and Steel); Session on Nitrogen in Iron Alloys and Metallography; Blackstone Hotel
12:00 M. National Metal Exposition opens; International Amphitheatre
12:00 M. ⊕ Canadian Luncheon; Palmer House
12:15 P.M. A.I.M.E.; Openhearth Executive Committee Luncheon Meeting; Blackstone Hotel
12:30 P.M. ⊕ Past Presidents' Luncheon; Palmer House
2:00 P.M. ⊕ Technical Session; International Amphitheatre
2:00 P.M. A.I.M.E. (Institute of Metals); Session on Constitutional Diagrams; Blackstone Hotel
2:00 P.M. A.I.M.E. (Iron and Steel); Session on Blast Furnace Operation and White Cast Iron; Blackstone Hotel
2:00 P.M. A.W.S.; Simultaneous Sessions on Fundamental Research and Welded Equipment; Stevens Hotel
4:30 P.M. ⊕ Lecture Course, Alloying Elements in Steel; International Amphitheatre
6:15 P.M. Missouri School of Mines and Metallurgy Alumni Dinner; Saddle and Sirloin Club
7:00 P.M. A.I.M.E.; Cocktail Party; Blackstone Hotel
7:30 P.M. A.W.S.; Fundamental Research Conference; Stevens
8:00 P.M. A.I.M.E.; Annual Autumn Dinner; Blackstone Hotel
8:00 P.M. ⊕ Lecture Course, Visual Examination of Steels; International Amphitheatre
10:30 P.M. National Metal Exposition closes

Wednesday, Oct. 25, 1939

7:30 A.M. ⊕ Chapter Chairmen's Breakfast; Palmer House
9:30 A.M. ⊕ Annual Meeting and Campbell Memorial Lecture; Palmer House
9:30 A.M. A.W.S.; Sessions on Flame Hardening and Hard Surfacing, and on Resistance Welding; Stevens Hotel
9:30 A.M. W.A. (Steel Division); Congress Hotel
9:30 A.M. W.A. (Non-Ferrous Division); Congress Hotel
12:00 M. National Metal Exposition opens; International Amphitheatre
12:00 M. College Alumni Luncheons; Palmer House
12:15 P.M. A.I.M.E. (Iron and Steel); Executive Committee Luncheon Meeting; Blackstone Hotel
1:00 P.M. W.A. Luncheon; Congress Hotel
2:00 P.M. ⊕ Technical Session; International Amphitheatre
2:00 P.M. A.I.M.E. (Institute of Metals): Session on Magnesium, Copper, Gold; Blackstone Hotel
2:00 P.M. A.W.S.; (*a*) Piping, Pressure Vessels and Boilers, and (*b*) Resistance Welding; Stevens Hotel
3:00 P.M. W.A.; Annual Business Meeting; Congress Hotel
4:30 P.M. ⊕ Lecture Course, Alloying Elements in Steel; International Amphitheatre
7:30 P.M. W.A.; Dinner and Stag Smoker; Congress Hotel
8:00 P.M. ⊕ Lecture Course, Visual Examination of Steels; International Amphitheatre
10:00 P.M. A.W.S.; Stag Party; Stevens Hotel
10:30 P.M. National Metal Exposition closes

Thursday, Oct. 26, 1939

9:30 A.M. ⊕ Simultaneous Technical Sessions; Palmer House
9:30 A.M. A.W.S.; (*a*) Cutting and Welding in Steel Mills and (*b*) Structural and Ship Work; Stevens Hotel
9:30 A.M. W.A.; Acid Disposal Symposium; Congress Hotel
12:00 M. National Metal Exposition opens; International Amphitheatre
2:00 P.M. ⊕ Symposium on Precipitation Hardening; International Amphitheatre
2:00 P.M. A.W.S.; Committee Meetings; Stevens Hotel
4:30 P.M. ⊕ Lecture Course, Alloying Elements in Steel; International Amphitheatre
6:00 P.M. National Metal Exposition closes
6:30 P.M. ⊕ Annual Banquet; Palmer House
7:00 P.M. A.W.S.; Annual Banquet; Stevens Hotel

Friday, Oct. 27, 1939

8:30 A.M. ⊕ Lecture Course, Alloying Elements in Steel; Palmer House
9:30 A.M. ⊕, Precipitation Hardening; Palmer House
9:30 A.M. A.W.S.; Simultaneous Sessions on Railroads and Miscellaneous Subjects; Stevens Hotel
11:30 A.M. A.W.S.; Business Meeting; Stevens Hotel
12:00 M. National Metal Exposition opens; International Amphitheatre
2:00 P.M. ⊕ Symposium on Precipitation Hardening; International Amphitheatre
10:30 P.M. National Metal Exposition and National Metal Congress end

Technical Meetings

Monday's Program: October 23, 1939

First Morning Session

(Simultaneous)

A search for some less expensive material for **resistance to low temperature embrittlement** than the austenitic stainless steels and non-ferrous metals produced a series of normalized and drawn **nickel and nickel-molybdenum steels** which do the job very well, according to T. N. Armstrong and A. P. Gagnebin.

For the elimination of coarse dendrites, or **raising the grain-coarsening temperature** of forging steels, definite **residual titanium** contents in the steel are necessary and not mere deoxidation with titanium. Such is one of the conclusions reached by George F. Comstock of Titanium Alloy Mfg. Co.

While practically every tool manufacturer uses the process involving **molten cyanides for nitriding high speed steel,** a detailed but practical study of the process by J. G. Morrison and J. P. Gill is the first paper on the subject ever to be published.

On the basis that **high speed steel forgings** are a better material for cutting tools than high speed steel bar stock, W. H. Wills proceeds to give some practical pointers on the manufacture of such forgings.

Second Morning Session

(Simultaneous)

Interest in impact testing continues apace and O. V. Greene and R. D. Stout tackle the **torsion impact test** by means of an interpretation of its stress-strain characteristics. These curves, they say, give a clear conception of the strength and ductility components in the test.

Damping capacity may be simply described as the ability to "damp" or absorb vibrations, but its mechanism is far more complicated than this, and is not yet fully understood. General Electric's E. R. Parker takes another step toward understanding with a study on the **influence of magnetic fields.**

A variety of steels of widely differing chemical compositions and heat treatments is used to demonstrate the validity of three empirical equations expressing the **interrelation between stress and strain in the tensile test.** The equations were developed by E. J. Janitzky and M. Baeyertz of Carnegie-Illinois' South Works.

Continuing some investigations on surface treatment of metals begun four years ago and first reported in the *Transactions* for 1938, Kehl and Offenhauer of Lehigh University now tell how **acid pickling** can be controlled to maintain good fatigue properties in the metal after it is cleaned in acid.

One Afternoon Session

Correlation of long-time and **short-time creep tests** has long been a serious problem of testing engineers attempting to develop suitable and easily executed acceptance tests. By using temperature rather than load as a variable, Kanter and Sticha of Crane Co. tackle the problem from a somewhat different standpoint.

Hildorf, Clark and White, continuing a long series of investigations on properties of steels at high temperature, report the **strengthening effect of vanadium and molybdenum.** Short-time tensile tests, rupture tests and micro-examination provide new data on 21 sheets with 5 to 7% chromium.

First fruits of three years of intensive work on the little-understood problem of **stress corrosion cracking of stainless steel** take the form of an exhaustive paper by J. C. Hodge and John L. Miller containing some valuable data and conclusions. Its general tenor is given in a "Critical Point" in August METAL PROGRESS.

Complete absence of magnetism has long been a distinguishing property of austenite, which means that some well-established ideas may have to go by the board with the discovery of **ferromagnetic austenite** by L. P. Tarasov and E. R. Parker of General Electric's Research Laboratory.

Two Lecture Courses

Afternoon

Edgar C. Bain, past-president, begins a series of lectures on **The Functions of the Alloying Elements in Steel,** a summary of the recent studies at U.S. Steel Corporation Research Laboratories, and elsewhere, which have systematized this hitherto complex subject.

Evening

George M. Enos, associate professor of metallurgy at University of Cincinnati, gives the first of three lectures on **Visual Examination of Steels,** in which he discusses the technique of low power microscopy and photography and the interpretation of the records so made.

National Metal Exposition Opens at Noon

Metal Progress; Page 328

Technical Meetings

Tuesday's Program; October 24, 1939

First Morning Session

(Simultaneous)

W. P. Wallace and R. L. Rickett have undertaken to extend the limited literature now existing on the influence of **annealing** conditions on structure and properties of **low carbon cold-reduced steels.**

Cramer and Bast give further data on prevention of the internal cracks which sometimes infest large forgings known as **flakes,** and the similar defect in heavy rails known as "internal transverse fissures". Their experiments determine the length of time necessary to hold railroad rails at various temperatures to prevent the formation of such damaging fissures.

Selection and heat treatment of gear steels is discussed by H. B. Knowlton and E. H. Snyder on the basis of service experience and laboratory tests. A special gear dynamometer and new type of rolling fatigue machine are particularly interesting.

Second Morning Session

(Simultaneous)

The names of Boston and Gilbert are so closely associated with fundamental investigations on cutting tools that their appearance on the program is a sure indication of some new and interesting data. This time they tell about the relation of physical properties and microstructure to **machinability of medium carbon steel.**

Results of tests on **leaded steels** are compared to average properties of similar non-leaded materials. The authors, Robbins and Caskey, conclude that while much work remains to be done, the steels have amply demonstrated their desirable characteristics.

"An important contribution to an important problem" characterizes H. Y. Hunsicker's paper investigating the adverse effect of iron on **precipitation hardening of aluminum-copper alloys.**

Of particular value to the man who designs the tools as well as the man in the shop is Weber and Weinzierl's paper on **drawing aluminum.** The principles of the drawing operation, as stated by the authors, may also be applied to other metals and alloys.

One Afternoon Session

Jominy, originator of the end-quench **hardenability test,** best suited to alloy steels, has now devised a method for adapting it to the **shallow hardening,** plain carbon steels.

Aqueous quenching media are the most active quenching agents available but, in certain circumstances, suffer the disadvantage of causing soft spots. A test method evolved by F. W. Trembour and Howard Scott determines the optimum concentrations for various water-salt solutions and distinguishes two types of soft spots.

A sequel to last year's **hardenability** symposium covers some investigations made with the **end-quench test** by Gordon Williams. He finds it gives excellent reproducibility of results and believes it should find extended use for the acceptance testing of alloy steels.

When the cooling rate of a piece of steel is interrupted during quenching **(time quenching),** concentric rings which differ structurally are produced. John L. Burns and Victor Brown explain the phenomenon on the basis of the "S" curve.

Two Lecture Courses

Afternoon

While it is frequently said that economical use requires heat treatment of alloy steels, Doctor Bain shows how certain elements form high strength, low alloy steels, used in the as-rolled condition.

Evening

Remember 'way back when there was bitter controversy between steel producer and consumer every time the latter attempted to reject a shipment that was pock marked after a deep etch? Professor Enos' second lecture tells the "do and don't" of this test.

National Metal Exposition

Afternoon

Many meetings of technical societies may fairly be criticized as being too theoretical, dominated by research men and scientists. ⊜ will never go that way, since the National

Evening

Metal Exposition, held under ⊜ sponsorship and control, provides a view of all recent developments in practical metallurgy, metal-working equipment, and metallurgical products.

Technical Meetings

Wednesday

Morning Session

A program of physical testing to study the application of hardened carbon steel to services requiring resistance to impact and wear **correlates hardness and temperature with strength, ductility and toughness.** To be presented by S. W. Lyon of University of Illinois.

A study of **depth hardening characteristics** of steels has been undertaken by the ASM Metals Handbook Subcommittee on Alloying Elements, at Battelle Memorial Institute. The first part of the program covering 16 S.A.E. steels is now reported by P. Klain and C. H. Lorig.

H. A. Schwartz and collaborators have previously studied **graphitization** in white cast iron by examining the effect of certain elements that retard the process. They now try the opposite tack and report the **accelerating effect of copper and nickel.**

Afternoon Session

Thomas G. Digges has observed that when carbon is not uniformly distributed in austenite the specimens are **incompletely hardened on transformation.** The present study investigates the mechanism of this phenomenon.

New light on the problem of **austenite → martensite transformation** clarifies part of the picture presented by the "S" curve and substantiates an earlier concept never before proved. A. B. Greninger and A. R. Troiano are the authors.

Concluding that the properties of a mixed microstructure can be understood only when the properties of the individual components are known, Carnegie Tech's Gensamer, Pearsall and Smith report on tensile and other mechanical **properties of the decomposition products of austenite.**

New methods for practical heat treatment issue from the observation by Payson, Hodapp and Leeder that a **spheroidized structure** can be obtained by **direct transformation** of austenite

Afternoon Lecture

Influence of alloying elements, in solution in austenite, in slowing up its transformation into hard martensite will be discussed in Bain's lecture.

Evening Lecture

Sulphur prints, magnaflux and other visual inspection methods will be the concluding topics in Enos' lecture series.

Thursday

First Morning Session

Air-hardening **toolsteels** can be **bright hardened** by gas cooling in an atmosphere that eliminates oxidation and decarburization and avoids distortion and cracking. Method, atmosphere, and equipment are described by J. R. Gier and Howard Scott.

In attempting to prepare an accurate table of **hardness conversion relations** between the various important instruments and scales, a great deal of experimental work was required by Howard Scott and T. H. Gray. (Their final chart appears on page 379 of this issue of METAL PROGRESS.)

The **hardenability** characteristics of the 12 principal types of **toolsteel** have been studied by A. J. Scheid, Jr. of Columbia Tool Steel Co., and the results are presented in such form as to be of practical use in the selection and hardening of toolsteel.

Second Morning Session

A systematic exploration of the **nickel-tungsten system** reveals some interesting precipitation hardening characteristics in the nickel-rich compositions — an additional study of an alloy system from the laboratories of G.E.'s Cleveland Wire Works. F. H. Ellinger and W. P. Sykes are the authors.

Experiments on **oxidation of steel** have been carried on over a period of years at University of Michigan. Latest results by C. A. Siebert and H. G. Donnelly show that steel scales more **in a humidified furnace atmosphere** than in a dry one.

A novel technique of **heat etching** provides the only practical, non-carburizing method available today for **revealing austenite grain size** in very low carbon steels, say M. J. Day and J. B. Austin.

A detailed picture of the **tempering process for high speed steel** (by Morris Cohen and P. K. Koh) presents a straightforward explanation of the reported differences obtained from multiple tempering as compared with single tempering.

Afternoon Session

On precipitation hardening; see right hand page.

Afternoon Lecture

Some alloys enter stable and complex carbides, which prevent grain growth in hot austenite and produce a tough steel after hardening — the gist of the fourth lecture on Alloy Steels.

Banquet in the Evening

National Metal Exposition

On Wednesday the National Metal Exposition will be open from 12 noon to 10:30 P.M.

On Thursday the Exposition will close at 6 P.M. to enable everyone to attend the banquet.

Technical Meetings

Thursday Afternoon and Friday, October 26 and 27, 1939

Symposium on Precipitation Hardening

Thursday Afternoon

Dr. Jeffries' **introduction to the precipitation hardening** symposium deals briefly with the historical aspects of the process and its importance in the development of metallurgical products and processes. (See also Wilm's original paper, reprinted in last month's METAL PROGRESS.)

L. W. Kempf then reviews the more important considerations in the development and utilization of solution and **precipitation hardened aluminum alloys.** Forecasting the properties of specific compositions is as yet impossible; methods are still essentially empirical.

New data on the effect of a third element on the room temperature **aging of high purity aluminum-copper alloys** are included in Fink, Smith and Willey's contribution to the symposium.

Iron-tungsten and iron-molybdenum alloys represent the **heavy metals** in heat treatable alloys of the harder class. Much new information is included in Sykes' report on their precipitation phenomena.

Friday Morning

Treatment, properties and commercial applications are stressed by D. K. Crampton for the **19 copper-base alloy systems capable of age hardening.**

Magnetic methods, in addition to the usual hardness, electrical resistance and metallographic studies, are applied by Gordon and Cohen to an investigation of **age hardening in a copper-cobalt and a copper-iron alloy.**

Age hardening of precious metal alloys actually preceded Wilm's discovery of duralumin, say Vines and Wise in discussing these materials whose widest applications are in the dental industry and the jewelry industry, although the field might well be broadened.

The almost innumerable variety of **nickel alloys** and the relatively few systematic studies of their **dispersion hardening** combine to form a good basis for a paper on this subject. International Nickel Co. provides authorship by N. B. Pilling and A. M. Talbot.

In a critical review of the published work on **aging of iron and steel** Kenyon and Burns attempt to present the best explanation of the mechanism of strain and quench aging.

Friday Afternoon

R. H. Harrington's careful investigation (at General Electric Research Laboratory) into the **role of strain in precipitation** reactions suggests to him that a vast amount of research remains to be done and that the principles he outlines should serve only as tools for further development.

R. F. Mehl and L. K. Jetter attempt to reconcile divergent points of view in their discussion of **age hardening theory.** They point out that while the process is of great industrial importance, it is also of unusual scientific interest. It will be well worth while to come to this last session, for Mehl's presentation can be counted on to be highly interesting. A preview of his paper is on page 376 of this issue.

Final Lecture on Alloying Elements

Put in a call for early breakfast on Friday morning, so you will not miss Edgar Bain's final lecture at the unprecedented hour of 8:30 A.M. In it he will show how the sluggish diffusion of alloying elements and stable carbides at all temperatures produce hard and tough steels, toolsteels and creep resistant steels.

Inspection Trips

Each morning, except Monday, buses will leave Palmer House at 8:30 for the following points, for ASM members properly registered in advance and presenting tickets. Each trip will require the entire morning.

Tuesday, October 24

International Harvester Co. Tractor Works or
Acme Steel Co. and American Can Co. (Englewood Plant).

Wednesday, October 25

Carnegie-Illinois Steel Co. South Works or
A Finkl & Sons Co. and Lindberg Steel Treating Co.

Thursday, October 26

Inland Steel Co. or
Mills Novelty Co., Belden Mfg. Co., and Stewart Warner Co. (any two).

Friday, October 27

Youngstown Sheet & Tube Co. or
Western Electric Co.
Chicago Latrobe Twist Drill Co. (by taxi).

The National Metal Exposition

Last chance to attend: Noon to 10:30 P. M.

American Society for Metals

THE OBJECT OF THE SOCIETY SHALL BE TO PROMOTE THE ARTS AND SCIENCES CONNECTED WITH EITHER THE MANUFACTURE OR TREATMENT OF METALS, OR BOTH.

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SIR ROBERT HADFIELD
CHARLES F. KETTERING

HENRY MARION HOWE MEDALISTS

EMANUEL J. JANITZKY	1922	HERBERT J. FRENCH	1930	JOHN CHIPMAN	1934
FRANCIS F. LUCAS	1924	EDGAR C. BAIN	1931	TRYGVE D. YENSEN	1935
HORACE H. LESTER	1925	KARL HEINDLHOFER	1931	NICHOLAS A. ZIEGLER	1935
†FREDERICK C. LANGENBERG	1926	FRANCIS M. WALTERS	1932	A. G. H. ANDERSEN	1937
WESLEY P. SYKES	1927	CYRIL WELLS	1932	ERIC R. JETTE	1937
OSCAR E. HARDER	1928	MAXWELL GENSAMER	1932	JOSEPH WINLOCK	1938
RALPH L. DOWDELL	1928	JOHN F. ECKEL	1932	RALPH W. E. LEITER	1938
†CARL R. WOHRMAN	1929	JOSEPH V. EMMONS	1933		

SAUVEUR ACHIEVEMENT MEDALISTS

†ALBERT SAUVEUR	1934	ZAY JEFFRIES	1935	HARRY W. McQUAID	1938
		WILLIAM R. CHAPIN	1936		

PAST-PRESIDENTS

ALBERT E. WHITE	1921	J. FLETCHER HARPER	1927	WILLIAM B. COLEMAN	1933
FRANK P. GILLIGAN	1922	FREDERICK G. HUGHES	1928	WILLIAM H. PHILLIPS	1934
†TILLMAN D. LYNCH	1923	ZAY JEFFRIES	1929	BENJAMIN F. SHEPHERD	1935
†GEORGE K. BURGESS	1924	ROBERT G. GUTHRIE	1930	ROBERT S. ARCHER	1936
WILLIAM S. BIDLE	1925	J. MITCHELL WATSON	1931	EDGAR C. BAIN	1937
ROBERT M. BIRD	1926	ALEXANDER H. d'ARCAMBAL	1932	GEORGE B. WATERHOUSE	1938

† Deceased

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Business Address.....
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City.....*State*.....

Personals

Stewart G. Fletcher is now a half-time assistant in the department of metallurgy at Massachusetts Institute of Technology.

Joseph H. Kline, a Purdue graduate, is now employed in the chemical laboratory of Republic Steel Corp. in Canton, Ohio.

Alfred H. Rudrauff, B.S. in metallurgy, Penn State, 1939, is now an inspector in the metallurgical department of the Sparrows Point plant of Bethlehem Steel Co.

R. J. Raudibaugh is teaching metallography at Purdue University in the chemical and metallurgical engineering department, and working toward a doctorate.

G. Lewis Perkins, assistant metallurgist with the Sharon Steel Corp., has accepted a position with Rustless Iron and Steel Corp., Baltimore, as assistant production metallurgist.

G. C. Jenison has resigned as chief chemist in charge of the chemical laboratory, research department, Continental Can Co., Inc., Chicago, to accept a position in the quality control department of the Weirton Steel Co., Weirton, West Va.

A. J. McDonald, formerly vice-president in charge of sales for the Lebanon Steel Foundry, now holds a similar position with the American Steel Castings Co. of Newark, N. J.

Arthur B. Wilder is now research metallurgist with Jones and Laughlin Steel Corp., Pittsburgh, Pa.

Appointed to the department of metallurgy, University of Notre Dame: **Alexander R. Troiano**, formerly of Harvard University. **Dugald C. Jackson, Jr.**, formerly president of the Lewis Institute in Chicago, has been made dean of the college of engineering.

Appointed as instructors in metallurgical engineering in the department of mining and metallurgical engineering of the University of Illinois: **Earl J. Eckel**, formerly in the metallurgical department of Carnegie-Illinois sheet and tin mill, Gary, Ind.; **John A. Snyder**, formerly junior metallurgist, Inland Steel Co., Indiana Harbor, Ind.; **Bernard G. Ricketts**, formerly with United States Geological Survey.

Promoted by Revere Copper and Brass, Inc.: **R. Carson Dalzell**, to technical advisor to the Baltimore division.

Don A. Campbell, formerly special engineering representative for the Eclipse Fuel Engineering Co., has been made district manager for Wheelco Instruments Co. covering New York, New Jersey and Connecticut.

METAL CLEANING ENGINEERS
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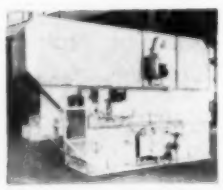
DETROIT REX PRODUCTS

1940 CLEANING METHODS For Finishing and Heat-Treating

Vapor-slush type Detrex Degreaser used with electric lift to clean parts after oil quenching.



Conveyorized 3-dip Detrex Degreaser used for cleaning prior to painting, plating or inspection.

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Your requirements for fast, flexible and economical cleaning will be met by a Detrex Degreaser.

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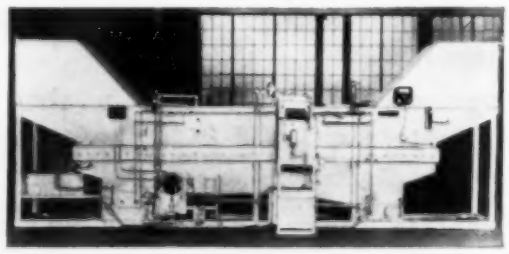
Complete information on the Detrex equipment or solvents best suited to your particular requirements is yours for the asking. Or better yet, let a Detrex engineer consult with you.



Straight-through type of Vapor-Spray-Vapor Detrex Degreaser with continuous solvent still. Machine shown used on production line in automobile plant.

DETREX means ENGINEERED QUALITY

DETROIT REX PRODUCTS COMPANY
Engineered Solvent Degreasing and Alkali Cleaning
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Branch Offices in Principal Cities

Personals

R. A. Smith, formerly instructor in the department of metal processing, University of Michigan, is now metallurgist with Sears, Roebuck & Co.

David A. Wigton has completed his course at Colorado School of Mines and is now an apprentice engineer in the metallurgy department of the National Tube Co., Lorain, Ohio.

Thomas W. Frank has transferred from the metallurgical laboratory at Timken Roller Bearing Co. to the plant engineering department at Copperweld Steel Co., Glassport, Pa.

Honored by the American Society for Metals for ten consecutive years as secretary of the Ontario Chapter: **L. F. Fitzpatrick**, manager, Flexible Shaft Co., Ltd., Toronto, Canada.

Convention lecturers: **E. C. Bain**, past president and assistant to the vice-president in charge of metallurgy and research, United States Steel Corp., who will give five lectures on "Functions of Alloying Elements in Steel" during the National Metal Congress in Chicago; and **George M. Enos**, associate professor of metallurgy, University of Cincinnati, who will give a three-lecture course on "Visual Examination of Steels".

Elected vice-president in charge of sales, Continental Steel Corp., Kokomo, Ind.: **Edmond P. Severns**, formerly general manager of sheet sales.

Appointed head of the metallurgical department of Cleveland Tractor Co.: **Warren A. Silliman**, for the past six years assistant to **Gordon T. Williams**, who was made metallurgist of the testing and research laboratories of Deere & Co. on Oct. 1 (not previously, as erroneously reported in September METAL PROGRESS).

George O. O'Hara has been appointed sales manager for the electrode division of Great Lakes Carbon Corp.

William E. Wickenden, president of Case School of Applied Science, will be the principal speaker at the banquet meeting of the Porcelain Enamel Institute Forum in Columbus Oct. 19.

Edmund S. Davenport metallugist, U. S. Steel Corp. Research Laboratories, has been selected to deliver the Edward deMille Campbell Memorial Lecture of the American Society for Metals on Oct. 25 during the National Metal Congress in Chicago.

F. E. Fuller is now with Allison Engineering Co., Indianapolis, Ind.

Production Cleaning
With DETREX
Alkali Washers and Compounds

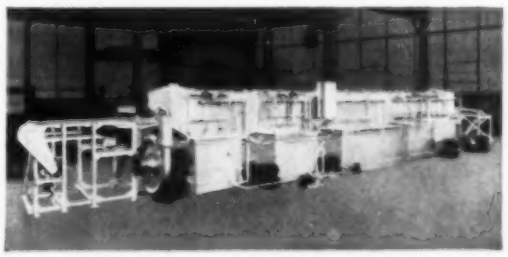
You name the alkali washing or stripping operation required on the parts you manufacture. Detrex engineers will provide the machine to do your job effectively at the lowest possible cost.

And whatever your operation, you will find the right compound in the complete line of Triad Cleaners and Strippers for fast, economical and efficient cleaning. To insure you best results, Detrex field engineers check the working efficiency of your cleaning solutions with modern control equipment as shown above.

Here is the one dependable source for *all* of your cleaning requirements. Let us furnish you with full details.

Single-stage, spray-type Detrex Alkali Washer. Baskets of work are carried through machine on roller conveyor.

Twin three-stage Detrex Alkali Washer of the through-monorail conveyor type. Consists of pressure spray wash, hot water rinse, and air blow-off.



A typical Detrex spray installation consisting of alkali washer, rinses, chromic acid, Bonderite, and air blow-off.

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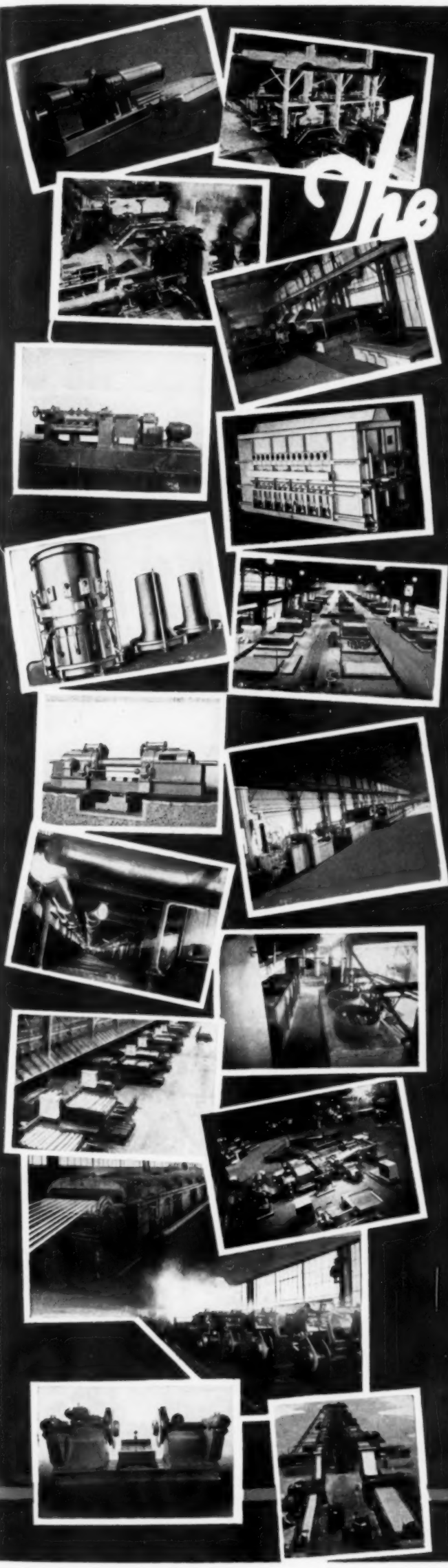
IT'S A GOOD INSTRUMENT TO USE BECAUSE BACK OF IT THERE ARE FRIENDLY AND COMPETENT PEOPLE SERVING YOU . . . ABOUT 300,000 OF THEM

BELL TELEPHONE SYSTEM



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To meet the flat rolled industry's constant demand for quality tonnage at low cost, The Wean Engineering Company, Inc., and its associate companies offer a complete engineering and equipment service.

Let us submit facts and figures whether you need one piece of equipment or a complete plant.

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Continuous Strip Coiling Equipment.
Special Conveying Mechanism.
Automatic Pilers.
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Strip Coil Holders.
Strip Coiling Reels.
Sheet Galvanizing Equipment.
Automatic Tinning Equipment.
Automatic Doublers.
Normalizing Furnaces.
McKay Levellers and Processing Units.
Strip Welding Equipment
Continuous Strip Pickling Equipment including: Uncoilers, Up-Cut Shears, Stitching Machines, Pinch Roll Units, Recoilers, Drying Machines, Pickling Tanks, and Auxiliary Equipment.
Scrubbing, Leveling, and Oiling Machines for Flat Products.
Wilson Vertical Tube Type Annealing Furnaces.
Corrugated Inner Covers.
Automatic Feeding and Catching Tables.
Continuous Pack and Pair Heating Furnaces.
Wheelabrator Abrasive Cleaning Equipment.
Automatic Weight Classifier.
Automatic Gauge Classifier.

SPECIALISTS IN SHEET, TIN AND STRIP MILL EQUIPMENT

Personals

Russell G. D. Fernald ⊜ has taken a position as junior metallurgist for Chile Exploration Co., Chuquicamata, Chile.

Swante C. Pirkola ⊜, B. S. in metallurgical engineering, Michigan College of Mining and Technology, 1939, is metallurgist in the cold reduction department, Inland Steel Co., at East Chicago.

S. A. Braley ⊜, chief metallurgical field engineer, rod and wire division, Pittsburgh Steel Co., will present the Mordica Memorial Lecture at the annual meeting of the Wire Association, on Oct. 25 during the National Metal Congress.

Featured speaker at the annual banquet of the ⊜ on Oct. 26: **R. E. Desvernine**, president of Crucible Steel Co. of America.

TODAY!
—MORE THAN EVER BEFORE
—AND BY ANY YARDSTICK
Stuart's
Cutting, Grinding
Deep Drawing
OIL PRODUCTS
SAVE MONEY FOR USERS!
Products that are original and different plus modern sales engineering total a service worthy of investigation by every economy-minded plant executive.
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John H. Birdsong ⊜ and **Albert H. Hall**, general analytical and consulting chemists and metallurgists, have acquired all of the stock of Buffalo Testing Laboratories, Inc. Hall has been elected president and Birdsong vice-president, secretary and treasurer.

Sydney Nashner ⊜ is now with Inland Steel Co., Indiana Harbor, Ind., as metallurgist concerned with flat-rolled products investigations.

Donald T. Goettge ⊜, Ohio State University, 1939, has been made assistant junior metallurgist in charge of coated and hot rolled products at the sheet mill of Carnegie-Illinois Steel Corp. in Gary, Ind.

Richard H. Kaulback ⊜ secured a position in the research laboratory of the Crucible Steel Co. of America, Atha Works, Harrison, N. J. after graduation from Massachusetts Institute of Technology last June.

Victor O. Allen ⊜, for the past five years associated with the Radio Corp. as consulting and research engineer, has been named technical director of the Wilbur B. Driver Co., manufacturers of alloy wire, Newark, N. J.

Arthur Lennie ⊜ has resigned from the metallurgical laboratories of Vanadium-Alloys Steel Co., Latrobe, Pa., to take a position in the research laboratory of the Pur-Pak division of Excello Corp., Detroit.

R. H. Soll ⊜, chief metallurgist of the Emsco Derrick & Equipment Co. and D & B Pump & Supply Co. (a subsidiary), has been transferred back to the main plant in Los Angeles.

Ernest E. Thum ⊜ blushed under the barrage of compliments from editors, advertising managers and agency men on receipt of the plaque photographed on page 321 at the recent convention of the National Industrial Advertisers' Association.

NON-FERROUS METALS

METAL PROGRESS

OCTOBER 1939

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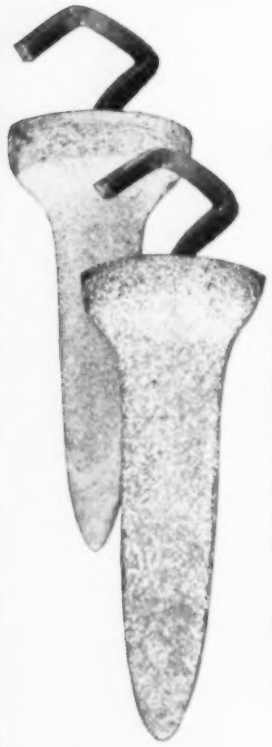
NOW—A Grain That Resists Disintegration

NOTE THE "SPOKE" LIKE CRYSTAL STRUCTURE!



Examples of the uniform corrosion common to Seymour "Seycast" Nickel Anodes. These and other illustrations on this page are from unretouched photographs.

Effective Answer To The Loose Nickel Nuisance

LOOSE NICKEL from anodes used in high acid plating baths is due to the attack of the acid on the bonding material between the grains of nickel, causing the grains as ordinarily bonded to fall off the body of the anode before they can be dissolved in the bath. This is largely overcome by the grain structure pictured here, as developed in the Seymour laboratories and obtainable in" Seycast" Nickel Anodes.

Note that the grains are long and narrow and extend to a common center. The acid attack can penetrate but a slight distance between the grain boundaries; hence the grains tend to remain firmly tied together until the anode is completely corroded.

SEYMOUR

"SEYCAST" High Efficiency Anodes

99% + PURE CAST NICKEL

THESE anodes were designed primarily for Bright Nickel plating, but are excellent wherever uniform corrosion, smooth deposit and economical operation are paramount. When used in sufficient numbers, practically no nickel salts need be added to the bath for replenishment. The envelope formed during corrosion is soft. Sludge is practically nil and remains within the bag. This, with the practical absence of loose nickel, makes a clean, even-corroding anode of exceptionally high efficiency. Recommended only for hot Watts baths with a pH of 4.5 electrometric or lower; i. e., for high acid baths.

"Seycast" Anodes will be displayed and Bright Nickel explained in Chicago, Oct. 23-27,

SEYMOUR BRIGHT NICKEL — An organic type process free from promoter metal, stable and easily controlled, producing brilliant deposits from a standard hot nickel bath. Operating conditions wide; pH from 2.0 to 4.5. Excellent throwing power.

AT NATIONAL METAL EXPOSITION

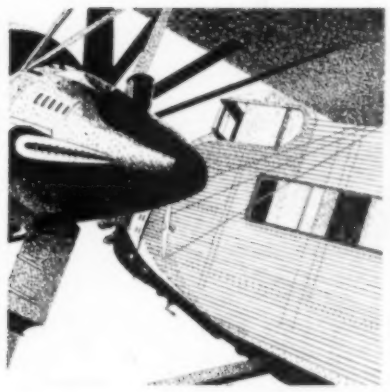
CALL AT BOOTH L-329 EXHIBIT OF

CROWN RHEOSTAT & SUPPLY COMPANY

Representative in the Chicago Territory of

THE SEYMOUR MANUFACTURING COMPANY

65 Franklin St., Seymour, Conn.



Non-Ferrous Metals

Castings
light, strong, non-tarnishable

By Harold J. Roast
Vice-President
Canadian Bronze Co., Ltd., Montreal

WHAT A CHANGE has come over strength per unit weight relationship!

Steel of the olden days with a unit weight of 490 lb. per cu.ft. and yield point in cast annealed condition of 40,000 psi. with an ultimate strength of 75,000, is, for instance, bowing to a complex aluminum alloy we call "ceralumin" containing copper, nickel, silicon, iron, magnesium, and cerium, giving a yield point of 60,000 and an ultimate strength of 70,000 psi. with a weight per cubic foot of 175 lb.

Thus, an alloy of almost one-third the weight of steel gives a yield point 50% greater.

How much further the unit weight can be reduced while the yield point is kept constant is difficult to state. So far as weight goes, we have the "elektron" alloys and "dowmetal", both of which give an alloy of only 112 lb. per cu.ft., but this is done at the sacrifice of strength as compared with the aluminum alloys. However, there seems to be no reason why other magnesium alloys may not be developed with three times their present strength, in which case a most notable saving in weight will become possible without a reduction in strength.

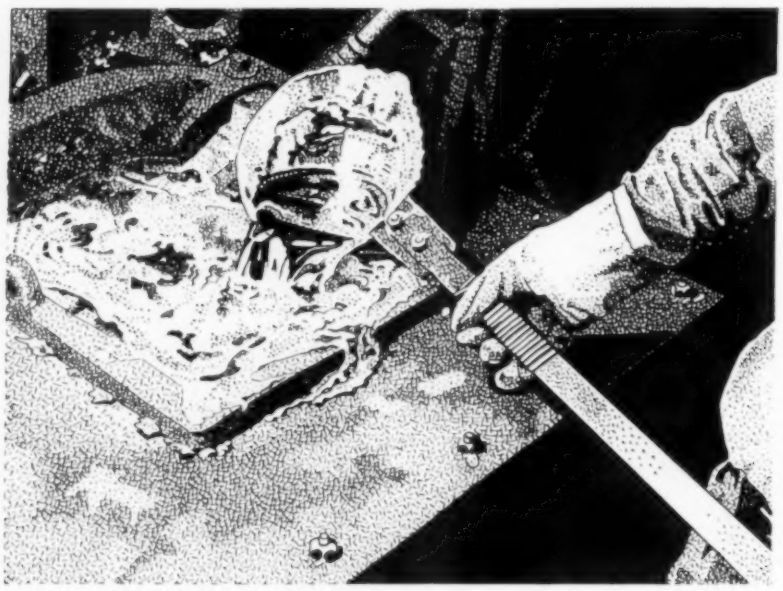
The general tendency to substitute worked metal for cast metal would seem to apply in great measure to these light alloys. The use of magnesium alloy thin sheet of considerably higher strength per square inch than the castings is another possibility in the fight for strength per minimum unit weight. However, all metal material, excepting powder metallurgy, has to originate in cast billets and the many problems surrounding the casting of the present magnesium alloys will probably be further complicated in the endeavour to obtain still further increased strength. Doubtless the foundry, which is rapidly becoming a highly scientific proposition, will devise new ways and means of casting metal under inert gasses and other improvements that will finally conquer the difficulties.

It is interesting to note, when thinking of the great improvement of strength per unit weight of metals, that the archer long ago found that wood provided the best combination! Dry yew wood (*taxus brevifolia*) weighs per cubic foot only 40 lb. and has a yield point of 12,000 psi., in round numbers.

When we compare this with a magnesium

alloy which weighs nearly three times as much, we find that the yew wood is almost three times as strong, weight for weight, as the magnesium alloy, or if we compare it with the aluminum alloy, we find that yew is only one-quarter the weight and gives a strength two-thirds that of the aluminum alloys. (The mention of wood draws attention to the fact that there is a very decided return to the use of wood for propeller blades instead of metal ones.)

Whether or not any advance will be made in the nomenclature of alloys is doubtful. We have such a proprietary name as Dow, consisting of three letters, while at the same time we have an alloy Koltchougaluminium of 18 letters and five metals — aluminum, nickel, magnesium, copper and manganese. Let us hope that it will not be necessary to exceed this alphabetical conglomerate for the name of the ideal alloy of the future!



While we have gold as the standard non-tarnishable metal, it is far from practical for the stress and strain of daily life. The non-ferrous metals in general, together with their alloys, are limited by their corrodibility, both for artistic use and otherwise. It may be that science will find a way of introducing small amounts of other elements into such alloys as brass and bronze as to enable them to resist surface oxidation and so maintain their very pleasing color without the necessity of periodic polishing or lacquering.

This has been accomplished in the case of *stainless* steel and who shall say that it cannot be duplicated in the non-ferrous field?

Permanent Mold Aluminum Castings

By Sam Tour
Lucius Pitkin, Inc.
New York City

THE ART AND PRACTICE of pouring molten metal into permanent molds are centuries old. Permanent mold castings of aluminum have been articles of commerce for many years. Although production in the United States runs into millions of pounds per year, little has been written about the industry or the process. Specifications covering sand castings of the aluminum alloys have been available for many years, and specifications covering die castings of aluminum alloys were first presented in the American Society for Testing Materials 10 or 12 years ago. Recognizing the important field of permanent mold aluminum castings, the Committee B-7 on Aluminum and Light Alloys of the American Society for Testing Materials has now prepared specifications covering these castings. No explanation is offered as to why this branch of the industry has been so backward. It is hoped that more will be heard in the future.

Permanent mold aluminum castings are made from special alloys, somewhat similar to those used for sand casting and for die casting, a number of which have been developed. The castings have a finer grain structure than sand castings as the natural result of the more rapid solidification in the mold. These castings, therefore, respond to heat treatment somewhat better than do sand castings; strengths obtainable in both the as-cast and heat treated conditions are somewhat superior.

Permanent mold aluminum castings are substantially free from porosity. They do not contain the spongy centers which are so often found in die castings and which are largely responsible for blisters after heat treatment. Permanent mold aluminum castings are particularly amenable to anodic oxidation treatments for surface stability.

Without the pressures available in pressure die casting to force the metal to fill the mold, but with the chilling effect of a metal mold, it

is obvious that the art of casting centers around the problems of mold design, temperature of mold, coatings on the mold to prevent excessive chilling, gating, risering, metal temperature control and metal composition control. That these problems can be solved simultaneously, in order to produce on an economical basis, is evidenced by the millions of pounds of such castings being made each year.

The list of uses and possible uses is practically identical with the combined list of such uses for both sand castings and die castings. As their desirable properties become better known to engineers and users in general, we can expect a considerable increase in the number of applications, in the tonnage production, and in the size and intricacy of the parts made by this very useful process.

Die Castings

By J. C. Fox
Chief Metallurgist
Doehler Die Casting Co., Toledo, Ohio

DIE CASTINGS have assumed a great importance in many branches of industry and have been instrumental in the development of world wide markets for many domestic appliances. Zinc base and aluminum base alloys have contributed the most in this development, but of late magnesium and brass die castings are making rapid strides as shown by the increased number of applications and the total consumption during the last year.

A short time ago the cost of magnesium was quite prohibitive but now it is in a range sufficient to compete with aluminum on a volume basis. In fact, there are a number of instances where magnesium die castings have replaced aluminum die castings. The factors of lightness and ease of machinability as well as equally good physical properties have been responsible. The physical properties of some die-cast magnesium alloys without heat treatment compare very favorably with the same alloys sand cast and heat treated. This fact has prompted a number of airplane manufacturers to switch from magnesium sand castings to die castings, saving enough to make up the cost of dies. The development of better protective films and finishes for magnesium has also had an influence.

Manufacturers of portable tools, hand tools, sanders, grinders, body finishing equipment and similar parts where lightness is a necessary requirement, are utilizing a considerable number of magnesium die castings.

Like magnesium there has been a steady increase in the use of brass die castings during the past year. Their high tensile properties, wear resistance and corrosion resistance have made it possible to replace some steel parts and even some of stainless steel. Wherever brass die castings have been applied they have remained and been found indispensable.

Transmission synchronizer rings, door latch parts, striker plates, shifter shoes are a few of the parts for automotive use; brass die castings also are found on diesel engines, airplanes, typewriters, optical instruments and electrical equipment.

During the past year considerable progress has been made in the art of aluminum die casting. The high pressure casting machine is responsible for sounder castings with high physical properties.

Of particular interest is the increasing use of the anodizing treatment for aluminum die castings for corrosion resistance as well as for decoration. Although this treatment has long been used for protection, the greatest difficulty has been to obtain an oxide coating that would be uniform and free from ugly streaks. Now, by the proper casting technique, the right alloy and method of treatment, oxide coatings can be obtained which are not only protective against corroding media, but also of highly decorative appearance. A number of devices such as meat slicers and choppers, which are constantly subjected to moisture and salt, are utilizing this treatment.

It is also possible now to obtain good, uniform, adherent electro-deposits on aluminum die castings (as a result of a recent development) and this kind of finishes is being used more than ever before.

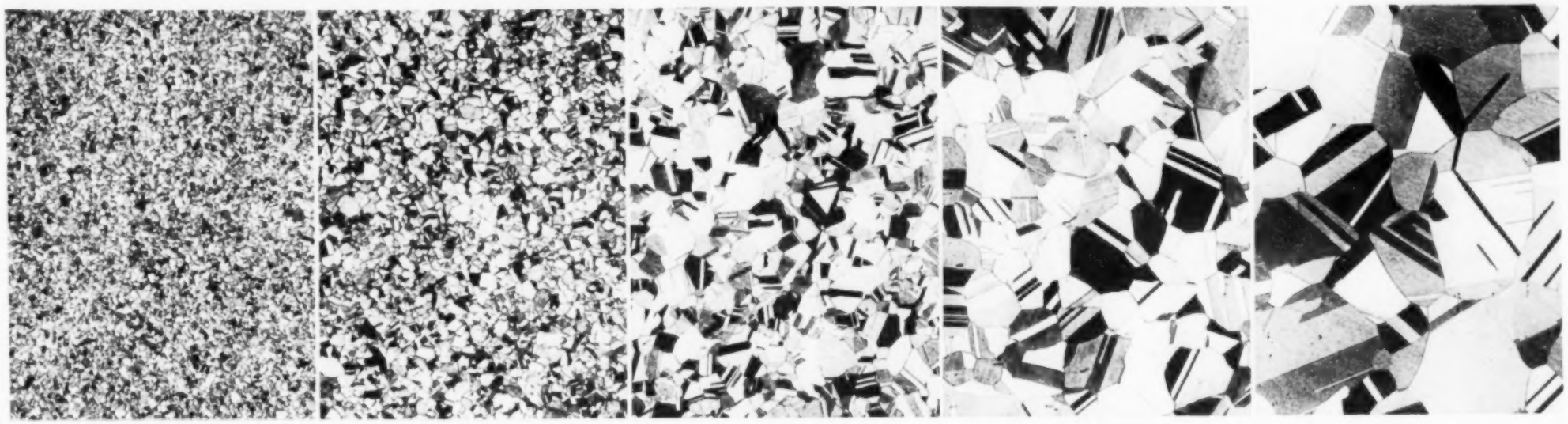
Zinc base alloy die castings continue to expand in application and consumption. The most noteworthy feature of the 1940 automotive use is their almost general acceptance for radiator grilles and other large parts in place of steel stampings formerly used. A number of motor companies have returned to the use of zinc die castings for these parts and several are using them for the first time. Among the latter is the Ford Motor Co., which has elected to use zinc die cast radiator grilles on all 1940 models.

The development of a new organic finish has encouraged a greater use of zinc in washing and other laundry machines, especially for

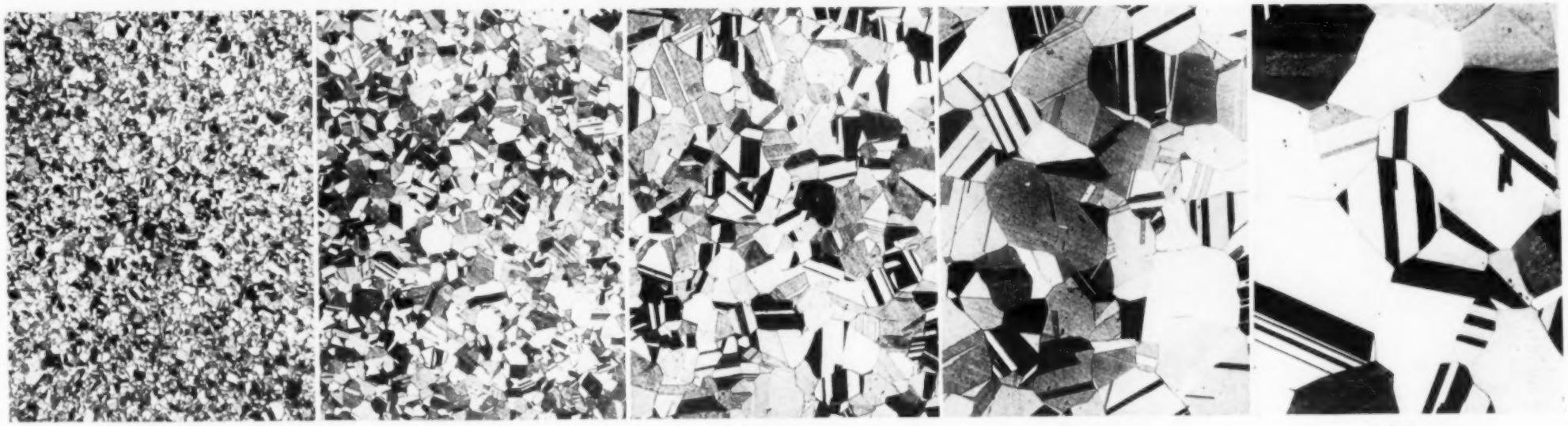
Standards for Estimating Grain Size (Non-Ferrous)

American Society for Testing Materials Standard E2-36 (copyrighted) for annealed materials such as brass, bronze, nickel silver

Actual diameter of average grain is noted; Magnification of micros: 75 ×



0.010 mm. 0.025 mm. 0.045 mm. 0.090 mm. 0.150 mm.



0.015 mm. 0.035 mm. 0.065 mm. 0.120 mm. 0.200 mm.

parts that are in direct contact with the soap and alkaline solutions.

Research and development continues to bring about radical changes in materials and methods. What may have been considered impractical last year is made possible this year. Thinner wall-sections are being now cast in dimensions previously thought impossible. Rates of production are steadily increasing.

High Pressure Castings

brass, thermo-plastic, aluminum

By Sam Tour
Lucius Pitkin, Inc., New York City

SOME YEARS AGO, the writer described the development of high pressure die casting equipment, particularly suitable for casting the brass alloys. This was designated as equipment using the "cold chamber process", producing castings by applying very high pressures to metal in the mushy or plastic stage.

Using this process along the lines in which it was originally developed for brass, the actual operation is quite similar to extruding. Instead of forming a long body with the contour of the orifice in the extrusion die plate, the cold chamber, high pressure, die casting process extrudes the plastic metal into a die cavity and there forces it to take the shape of that cavity. Several things are accomplished that had not been possible prior thereto. First, it is possible to produce brass die castings by being able to cast at a low enough temperature so that materials available for dies have an economically reasonable life. Second, it is possible to make castings in a temperature range where zinc fume and zinc deposition upon the dies does not cause trouble. Third, it is possible to make castings from these very high shrinkage alloys without the enormous amount of porosity which obtains when full liquid or molten metal pressure die casting is practised.

High pressure die casting equipment as thus originally developed for brass alloys has found an important place in the new industry of extrusion casting of thermo-plastics, and the great progress made in its application is largely confined to the latter field. One explanation offered by some for the lack of greater progress in brass die casting is the problem of die steels. While it is true that die life is the bottleneck in this application, it is also true that there has been a tendency to lose sight of one of the fundamentals upon which the process was developed, namely, the use of metal in the mushy or plastic range instead of in the molten or fully liquid condition. To the extent that attempts are made to work with liquid brass, the temperatures of operation are increased and the problem of die life becomes more important. While it is hoped that a better die steel can be and will be developed, it is believed that considerable progress can be made with the present steels if proper attention is paid to the problems of gating, die temperature, plunger speed, and pressures.

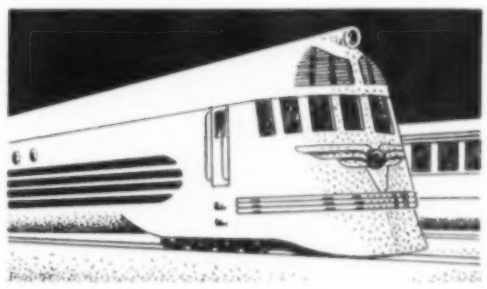
Although the die steel situation is an apparent bottleneck in the application of the high pressure die casting process to the production of castings of the copper-base alloys, it is not a very serious problem in the application of this process to the production of castings of the aluminum alloys. Much progress in this field can be looked for.

Bearings

By C. F. Smart
Metallurgist, Pontiac Motor Division
General Motors Corp., Pontiac, Mich.

RECENT PROGRESS IN BEARINGS has been more along structural lines than through the development of new or improved alloys. Silver, and silver-lead, and aluminum have been given some attention, but these are apparently still much in the experimental stage. In general, four types of materials are in extended use for bearing metals — lead base babbitts, tin base babbitts, cadmium alloys, and copper-lead alloys. Each of these appears to have a field of usefulness determined by maximum load, the ZN/P relationship between viscosity, r.p.m., and bearing pressure, the relation between unit pressure and surface velocity, the operating temperature, crankshaft material, design.

Powder metallurgy is proving useful in some phases of bearing manufacture; one bear-



ing soon to be available will be a new type copper-lead bearing, made by powder metallurgy processes, from chemically pure constituents, and uniformly distributed throughout the alloy. In another type of bearing a powder metallurgy composition is sintered on a steel back to serve as a mechanical reinforcement to a relatively thin layer of babbitt metal. Bearings with thin layers of babbitt, much thinner than generally accepted practice, are in use and are the subject of many experimental tests. Babbitt layers 0.003 in. thick applied over steel backs with an intermediate layer of bronze (the so called tri-metal bearings) have recently been introduced and some tests indicate that these have appreciably higher fatigue life than bearings with greater babbitt thickness. Favorable results with such tri-metal bearings have led to tests of similar thin babbitt layers applied directly over brass, bronze or steel and these offer promise of equal performance at a somewhat lower cost.

One bearing manufacturer has introduced diesel engine bearings on which the steel back has been replaced with a pre-compressed bronze casting, the idea being to obtain a dense casting to insure positive seating of the bearing back. The bronze back possesses bearing qualities as a protection to the shaft in event of babbitt failure.

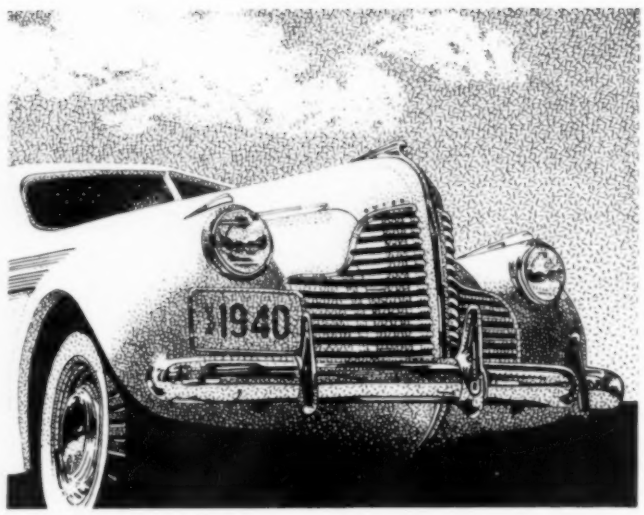
Electro-deposition of thin bearing metal layers as a method of producing bearings is in an experimental stage of development.

Powder Metallurgy

By Robert H. Leach
Vice-President, Handy & Harman
Bridgeport, Conn.

USE OF METAL POWDERS for the manufacture of different products has increased during the past year. Reports indicate that interest has broadened considerably and investigations are being conducted in the possibilities of substituting the processes used in powder metallurgy for the production of articles now made by the standard practices of melting, casting and fabricating.

Without attempting to establish any new classification of metal powder products, there are two fields in which powder metallurgy is particularly effective. In the first instance, we have its application to metals that are difficult to melt or combinations of metals that are not



miscible. Tungsten, tantalum, cemented carbides, nickel and silver, tungsten and copper, graphite and silver are typical examples of this group. The second field where powder metallurgy has proved to be of advantage is in the production of articles where uniform porosity within controllable limits is desired, such as bearings and bushings. Improvements and new developments promise further expansion in both these fields. There is no competition between metal powder processes and other methods in the production of these classes of materials and although the cost of raw materials and the cost of production are important factors, the fact that the same results *cannot* be obtained by any other means, gives powder metallurgy an unchallenged position.

Because of the lower temperatures at which this work is carried on there are possibilities in the use of metal powders for binders in the making of assemblies, parts of which might be damaged from the high temperatures required for either die or pressure casting, and where plastics are not satisfactory because the matrix should be metallic. Laminated or composite articles have been produced, corresponding to bi-metals or clad metals, of dissimilar materials in the different portions; there are possibilities of further development in this class.

The extent to which powder metallurgy will take over established methods of manufacturing certain types of metal products is impossible to prophesy. Experimental work and limited production has indicated that with suitable equipment and proper control of pressures and sintering temperatures it is possible to produce articles from metal powders which have physical properties that meet the requirements for parts now made by more conventional practices.

In general the cost of the raw material or metal powder is relatively high. There may be exceptions, but unless the cost of the raw material can be offset by the elimination of scrap or of expensive manufacturing operations, such as machining for example, or the finished article has properties not obtainable by other methods, it would appear to be doubtful whether the commercial substitution of processes will occur.

While it is true that knowledge of any metallurgical process is only gained by experience and improvements that come from exhaustive and careful study of the physical phenomena involved, it does not seem necessary to surround powder metallurgy with a veil of mysticism or to infer that the fundamental problems of powder metallurgy are not governed by the same laws that physical metallurgists are constantly investigating in all branches of applied metallurgy. One principal characteristic of metal powders that is self evident, is the large surface area for a given weight of material. For example, a piece of silver when ground to pass a 300-mesh screen, will have a total surface area in the order of several thousand times that of the original particle. The metallurgical problems in powder metallurgy therefore become involved with surface phenomena to such a degree that they may be the most important controlling factors in the success of the process. Effect of adsorbed films, chemical film formation, surface tension, vapor pressure are some of the problems to be investigated. Physical laws dealing with the flow of fine aggregates under pressure, relation of voids to size and shape of material, formation of ridges and flow structures, all have to be considered in the development of procedures that will give satisfactory results.

The fundamental metallurgical problems of powder metallurgy do not appear to be much different from those that the physical metallurgist encounters in dealing with metals or alloys in more massive form, and the same methods of study are applicable. In fact it is possible that the study of powder metallurgy will give physical metallurgists a better opportunity to observe phenomena that affect the melting, casting and fabrication of metals and alloys with the reasonable expectation that valuable information may be obtained leading to improvements in standard metallurgical practices.

The further development of sources of supply of suitable metal powders in the required quantities will influence the growth of powder metallurgy. Much experimenting is being done in the production of metal powders and future developments are awaited with interest.

Powder metallurgy has already demonstrated its value to industry and further expansion may be expected.

Improvements in Tubes

By Alan Morris
Chief Metallurgist, Bridgeport Brass Co.
Bridgeport, Conn.

THE TREND OF DEVELOPMENT in tube mill practice is guided by the increasingly exacting demands for better quality, closer dimensional tolerances, new alloys for new purposes, and more rapid deliveries. At the same time, much of this must be accomplished at little or no increase in cost of production.

These requirements have motivated the adoption in recent years of the extrusion press, the tube reducing process and bright annealing.

Just as the requirement for better steam condenser tube material has led to the use of copper-nickel and aluminum brass, so the more severe and varied requirements of the oil refining industry are stimulating research to find new and better alloys for its use. Exchangers are used for transfer of heat from vapor to water, oil to oil, vapor to oil, vapor to vapor, or oil to water. Temperatures and pressures are sometimes high. What with brine, hydrogen sulphide and ammonia, many of the conditions are extremely corrosive and constitute a challenge to research. Sometimes it is not possible to find among the alloys at present known one which is resistant at the same time to both the inside and outside condition. Composite tubes are being used experimentally, with some promise of success. If this promise is fulfilled improvements in methods of production of composite tubes may be expected.

A need is felt for moderately priced tubes for high temperature and pressure applications. Obviously the alloy which would fill this requirement would be refractory and bring with it manufacturing difficulties which might call for modification of present production methods or development of new ones.

Requests for brass tubing in hard-drawn condition bring with them the need for a true relief anneal to avoid danger of season-cracking. The use of specially designed furnaces for this purpose will undoubtedly become general.

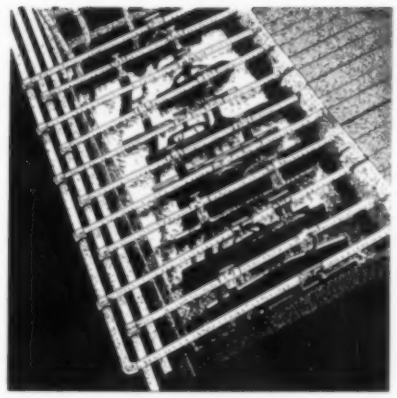
Copper and Its Alloys in Wrought Form

Prepared by M. G. Steele, Technical Adviser, Revere Copper and Brass, Inc.

Metal	Type Composition					Properties (Hard & Soft)			Forms	Properties and Uses	Methods of Working
	Cu	Zn	Pb	Sn	Ni	Tensile Strength	Elong-ation	Elastic Limit			
Copper (electrolytic)	99.9					51,000 32,500	4 47	48,000 12,000	Sheet; Bar; Tube; Rod; Plate	Corrosion resistance; ductility; high conductivity. Roofing; bus bar; high conductivity tubing	Stamp; Draw; Weld; Solder; Forge; Form
Copper (lake)	99.9	7 oz. silver per ton				51,000 32,000	4 47	48,000 12,000	Sheet; Strip; Rod	High annealing point. Auto radiator fins; lock seam tubing	Stamp; Draw; Solder; Form
Copper (phosphorized)	99.9	0.04 phosphorus max.				55,000 35,000	5 45	44,000 16,000	Sheet; Strip; Tube	Draws and coils better than electrolytic. Water, refrigerator and oil-burner tubing	Stamp; Draw; Forge
Copper (arsenical)	99.9	0.04 phosphorus 0.30 arsenic				60,000 36,000	4 40	55,000 7,000	Sheet; Tube; Plate	High strength; resists heat and flaking. Condenser tubes	Stamp; Draw; Forge
Copper (cadmium)	99	1.00 cadmium				80,000 35,000	4 45	68,000	Rod	High strength. High strength parts; trolley wire	Draw; Forge
Copper (beryllium)	98	2.00 beryllium				175,000 75,000	6 45	134,000 31,000	Sheet; Tube; Rod	Very high strength; hardness; high conductivity. Springs; cutting tools	Stamp; Draw; Forge; Form
Brasses											
Gilding metal	95	5				55,000 35,000	5 38	39,000 11,000	Sheet; Strip; Tube	Ductility; reddish gold color. Primers; detonator fuse caps; jewelry; forgings	Stamp; Draw; Forge; Form
Commercial bronze	90	10				67,000 37,000	3 40	53,000 11,000	Sheet; Strip; Tube	Ductility. Used for color match; stamped hardware; bullet jackets; jewelry; caskets; screen cloth	Stamp; Draw; Forge; Form; Perforate
Rich low brass	85	15				75,000 42,000	4 43	52,000 15,000	Sheet; Strip; Tube	Corrosion resistance. Brass pipe; jewelry; badges; name plates; etchings; tags; dials	Stamp; Form; Draw; Blank; Etch; Weld
Low brass	80	20				85,000 43,000	4 50	65,000 15,000	Sheet; Strip; Tube	Corrosion resistance; yellow color. Jewelry (for gold plating); fulton bellows.	Stamp; Form; Draw; Spin
Seventy-thirty or cartridge brass	70	30				86,000 45,000	4 50	65,000 15,000	Sheet; Strip Tube	High ductility; deep drawing. Pins; rivets; eyelets; radiators; cartridge shells; spun articles	Stamp; Spin; Deep Drawing
High brass	66	34				90,000 48,000	4 50	70,000 15,000	Sheet; Strip	High ductility; deep drawing. Brass pipe; auto reflectors; stampings; radiator fins	Stamp; Spin; Deep Drawing
Leaded high brass	65	33.5	1.5			80,000 45,000	5 60	60,000 15,000	Sheet; Strip	Forming by bending; free machining. Engravers' brass; lighting fixtures; clock and watch backs; gears; keys	Stamp; Form; Bend; Punch
Free cutting rod	62	35	3			62,000 47,000	20 60	25,000 15,000	Rod	Typical brass rod; free machining. Extruded shapes; screw machine parts	Machine; Thread; Extrude
Forging rod	60	38	2			70,000 50,000	10 45	31,000 15,000	Rod	Hot forgings; faucet handles; shower heads	Forge; Extrude; Machine;
Muntz metal	60	40				80,000 57,000	9.5 48	60,000 15,000	Sheet; Plate; Tubes	Condenser tubes and heads; ship sheathing; perforated metal; brazing rod	Draw; Punch; Forge
Architectural bronze	56	41.25	2.75			70,000 50,000	10 20	55,000 15,000	Sheet; Strip	Strength; hardness; free cutting. Extruded shapes; forgings; interior ornamental bronze	Extrude; Forge; Machine
Special Brasses											
Silicon brass	78	20	2.0 silicon			110,000 55,000	4 61	83,000 12,500	Sheet; Strip	High strength; weldability. Refrigerator evaporators; fire extinguisher shells	Resistance Weld; Stamp; Draw
Aluminum brass	76	22	2.0 aluminum			83,000 62,000	17 52	75,000 16,000	Tube	Resistance to corrosion and erosion; self healing skin. Condenser tubes	Draw; Extrude
Admiralty	71	28		1		95,000 45,000	5 60	92,000 18,000	Sheet; Strip; Tube	Resistance to corrosion, especially of sea water. Condenser tubes	Stamp; Draw; Extrude
Naval brass	60	39.25		0.75		75,000 54,000	15 45	39,000 15,000	Sheet; Rod; Tube	Resistance to corrosion in sea water. Tube heads; marine shafting; bolts; forged parts; window anchors	Draw; Forge
Bronzes											
Phosphor bronze	98.75	0.05 phosphorus		1.2		65,000 40,000	4 48	50,000 15,000	Sheet; Strip	Resilience; strength; hardness; corrosion resistance. Springs; bearings; small parts	Stamp; Form; Weld
Phosphor bronze	92	0.05 phosphorus		8		110,000 55,000	3 55	85,000 25,000	Sheet; Strip; Rod	Similar to above. Welding rod	Stamp; Form; Weld
Silicon bronze	96.25	3.25 silicon		0.50		110,000 60,000	5 55	100,000 25,000	Sheet; Tube; Rod	Strength; weldability; corrosion resistance. Tanks; bolts; screws; lags; chain; locomotive hub liners; welding rod.	Stamp; Draw; Forge; Weld; Extrude; Cast
Aluminum bronze	95	5.0 aluminum				105,000 57,000	5 55	80,000 24,000	Sheet; Tube; Rod	Corrosion resistance; strength; golden color. Condenser tubes; gift articles	Stamp; Extrude; Draw
Manganese bronze	59	39	1.25 Fe.	0.75	0.05 Mn	75,000 60,000	5 35	50,000 15,000	Sheet; Strip; Rod	Resistance to wear and corrosion. Welding rod; perforated coal screens; extruded wearing parts	Extrude; Perforate; Weld
Nickel-Silvers											
Nickel silver (typical)	65	20			15	93,000 58,000	5.5 45	75,000 15,000	Sheet; Strip; Rod	Resistance to corrosion; strength. Extruded shapes; table silver; instruments; key stock; springs	Forge; Extrude; Stamp
Cupro-Nickels											
Cupro-nickel (eighty-twenty)	80				20	80,000 49,000	3 42	78,000 17,000	Tube	Resistance to corrosion, erosion, heat and chemical attack. Condenser tubes	
Cupro-nickel (seventy-thirty)	70				30	84,000 49,000	4 50	83,000 18,300	Tube	Same as above but more resistant to corrosion. Condenser tubes	
Cupro-nickel (zinc alloy)	75	5			20	85,000 50,000	5 35	77,000 23,000	Sheet; Tube; Rod	Same as 80-20 above but less resistant to corrosion. Condenser tubes	

Electroplates

By Carl E. Heussner
Engineering Laboratories
Chrysler Corporation, Detroit



INDUSTRY and the consuming public have become quality minded regarding electroplated coatings. This knowledge will do much to advance the industry in the next few years. With the fine cooperation that exists between producer and consumer, we can expect great improvements.

There has been great progress made in the last few years with bright nickel and copper deposits, electro-color and anodic coatings. These have all been advances to promote quality and economy.

In the next five years we can expect to see the use of electro-deposits increased on present materials, on such newcomers as plastics, fabrics, and other molded material as well as a great extension of its use in the ceramic field. Most of these uses will be decorative, but there will also be extended use of electrolytic coatings for corrosion resistance and mechanical wear. Some applications that will undoubtedly advance will be selective deposits in gas media, and electro-deposits on marine work.

Alloy plating is showing considerable promise, and like the use of ferrous and non-ferrous alloy base materials, electro-deposits will be alloyed to give the final coating the desired surface appearance and physical properties.

It would appear as though the future outlook for the electroplating industry is very good, and the next five years will see tremendous progress in this field — which, as a matter of fact, has become a very scientific industry.

Trends in Copper Alloy Production

By D. K. Crampton
Director of Research
Chase Brass & Copper Co., Waterbury, Conn.

ONE TENDENCY in copper alloy production is toward larger units of metal, mechanical handling and continuous annealing, all of which tend toward greater production, lower cost and improved uniformity of product. In this connection, particular mention can be made of mechanical feed to large or break-down rolls, together with conveyor systems to facilitate the movement of heavy bars through the first stages of operation. The trend in melting furnaces is likewise toward larger units, partly to permit of greater unit weights, but more particularly to increase the economy.

In general, annealing furnaces tend more and more toward the continuous conveyor type with moving or roller hearths, and there is also a simultaneous development in strip annealing for wire and strip. One of the very interesting trends is that toward forced convection type annealing furnaces capable of operating up to quite high temperatures and having great flexibility of time and temperature cycles. In addition, they are outstanding as regards economy and uniformity, and usually incorporate atmospheric control and facilities for quenching or otherwise rapidly cooling. Incidentally, this development of forced convection type furnaces might bring about some reversal of the present trend toward conveyor furnaces. The uniformity of temperature inherent in the design largely overcomes the greatest objection to the older batch type furnaces. With this increased uniformity and recognized flexibility, there will probably be an increased number of them used for appropriate types of work.

There has been much activity in patenting of new alloys and the probability is that this will continue. Most of the patents cover modifications of previously known alloys rather than decidedly new ones. This of course is not surprising, as the field has been so intensively combed for so long a period.

One of the outstanding alloy developments has been the use of antimony, arsenic or phosphorus to prevent dezincification in admiralty and other condenser tube alloys subject to such attack. The trend is strongly toward these modified alloys, with the indication that they might supplant the older, unmodified materials. These elements are remarkably effective when used in practically any of the copper-zinc alloys, which in their absence might dezincify.

In the age hardening field, the copper-nickel-phosphorus alloys, with or without other elements, are among the most interesting

recently described, having unusually good combinations of strength and electrical conductivity, together with excellent fabricating qualities. They are well suited to such applications as trolley wires, telephone wires and transmission lines. It is expected that alloys of this type will be produced in considerable quantities in the coming years.

Patents were issued some time back on the use of sulphur and selenium, and of tellurium, for rendering copper alloys freely machinable, but no particular commercial application of these materials has been made until quite recently. The tellurium-bearing alloys are now being fabricated commercially both in rod and tube forms and show excellent combinations of machinability, forgeability and high conductivity, or of machinability, forgeability and hardenability. Already a considerable quantity of these alloys has been consumed and the indications are that this trend will continue.

Magnesium & Its Alloys

By L. B. Grant
Dowmetal Sales Manager
The Dow Chemical Co., Midland, Michigan

USE OF MAGNESIUM and its alloys has progressed very rapidly during the past year. Its more general acceptance by the aircraft industry has been particularly gratifying. The use of high pressure die castings in aircraft is readily expanding due to the sound, dense metal that can be obtained by this process and to the fact that larger production of airplanes results in quantities of castings large enough to absorb die expense.

Great advances are being made in the hot forming of magnesium alloy sheet. Deep draws have been made which were considered impossible a short time ago. We believe that the use of magnesium alloy in sheet metal form will be greatly expanded as these methods of hot forming become better known.

Magnesium alloys are tending toward higher purity following the same trend that zinc die casting alloys went through a few years ago. It is found that these higher purity alloys are greatly improving the basic corrosion resistance of the material. Major developments are also occurring in the methods of surface treating magnesium alloys prior to painting and they give remarkable resistance in sea shore and marine atmospheres.

Zinc and Its Alloys

By W. M. Peirce
Chief, Research Division
The New Jersey Zinc Co.
Palmerton, Pa.

PROGRESS in the applications of metallic zinc during the last decade has hinged largely around the commercial availability of zinc of 99.99% purity. Both the electrolytic and distillation processes are capable of still greater purity. (A tendency persists to apply the term "electrolytic" to all high purity zinc in spite of the fact that a very large proportion, if not a majority, of the 99.99% zinc produced in this country is distilled.) It is therefore natural that the possibilities of further advances along the lines of increased purity should have been thoroughly explored.

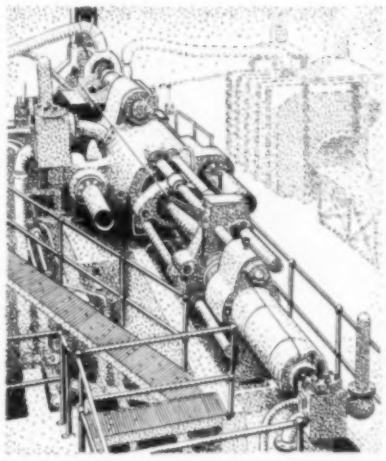
This has been done in the laboratories with which the writer is associated — and doubtless elsewhere — but without results so far as is known. In the die casting field no further improvement comes from zinc beyond the 99.99% which has been commercially available for some years. In the hot galvanizing and electro-galvanizing fields the same is even more true, since the advantage of 99.99 over the old 99.94% grade has been difficult to demonstrate except in special cases. In the brass field the use of 99.99 in preference to 99.94 has been almost entirely based on the additional tolerance for contamination, and the practical advantage of purity beyond 99.99% in this respect is doubtful.

From this analysis of the progress in the last decade, it would seem that we must look for future advances in the direction of better applications of the raw material already available. It is difficult to believe that the last frontier has been reached in alloys for casting or for rolling, even though the cream has been skimmed. However, it seems that any new developments will probably result from studies employing the most modern research tools of physical metallurgy.

In spite of the damaged reputation of galvanized roofing sheets, resulting from the thinly coated sheets marketed for the last 25 years, it is becoming more and more clearly recognized that heavy zinc coatings are the protection *par excellence* for steel. Improved methods of hot and cold galvanizing, and of spray coating, are to be expected. An important expansion in the

use of sprayed metal coatings appears to the writer to be inevitable.

A related use of metallic zinc which many believe is on the verge of a rapid expansion is the use of zinc dust paint for metal protection. Ideal as a hot dipped, heavy electro-galvanized, or sprayed coating may be, there will always remain those places where none of these methods is economically applicable and where paint must be relied upon for protection. Extensive testing programs carried out over a number of years have shown that zinc dust paints, particularly those formulated with moderate amounts of zinc oxide and iron oxide, are unequaled as priming coats next to the steel and they are, for many types of service, excellent finish coats. The use of such paint as a shop coat for structural steel, railroad cars, water tanks, and fresh water marine structures, to mention but a few examples, seems destined to progress rapidly now that non-gassing zinc dust is available and proper formulations have been worked out.



To summarize, raw material of more than adequate purity is already available in sufficient quantity, and advance in the zinc field during the years immediately before us depends upon progress in utilization of this raw material.

Aluminum and Its Alloys

By E. H. Dix, Jr.
Aluminum Research Laboratories
New Kensington, Pa.

PROGRESS in the aluminum industry during the past few years has been more in the nature of steady improvement in the products and expansion of manufacturing facilities than of spectacular new alloys or processes. Speaking generally, these improvements are not individually of large moment but, in the aggregate, they make for a wider and more successful use of aluminum and its alloys. Several developments, however, deserve special mention.

An outstanding accomplishment culminating in limited commercial application during the year is the successful brazing of aluminum alloys. This new process should undoubtedly broaden the use of aluminum alloys and cheapen the manufacture of articles now produced by other methods of jointing. The successful brazing of aluminum alloys is the result of the discovery of suitable fluxes and low melting point aluminum base brazing materials.

A new aluminum base die casting alloy known to the trade as Alcoa 218, with superior strength and resistance to corrosion, was announced during the year and bids fair to attain an important position in the field. The alloy contains, nominally, 8% magnesium, and develops a higher strength and elongation than any of the previously available aluminum die casting alloys.

Another product developed several years ago for a special application has entered the commercial field for more general use during the year. This material, Alclad (72S)3S, is a medium-strength, wrought product especially suitable for handling corrosive liquids, and will undoubtedly find wide usefulness for tanks and similar items of equipment. It is particularly suited for combatting localized corrosion and perforation.

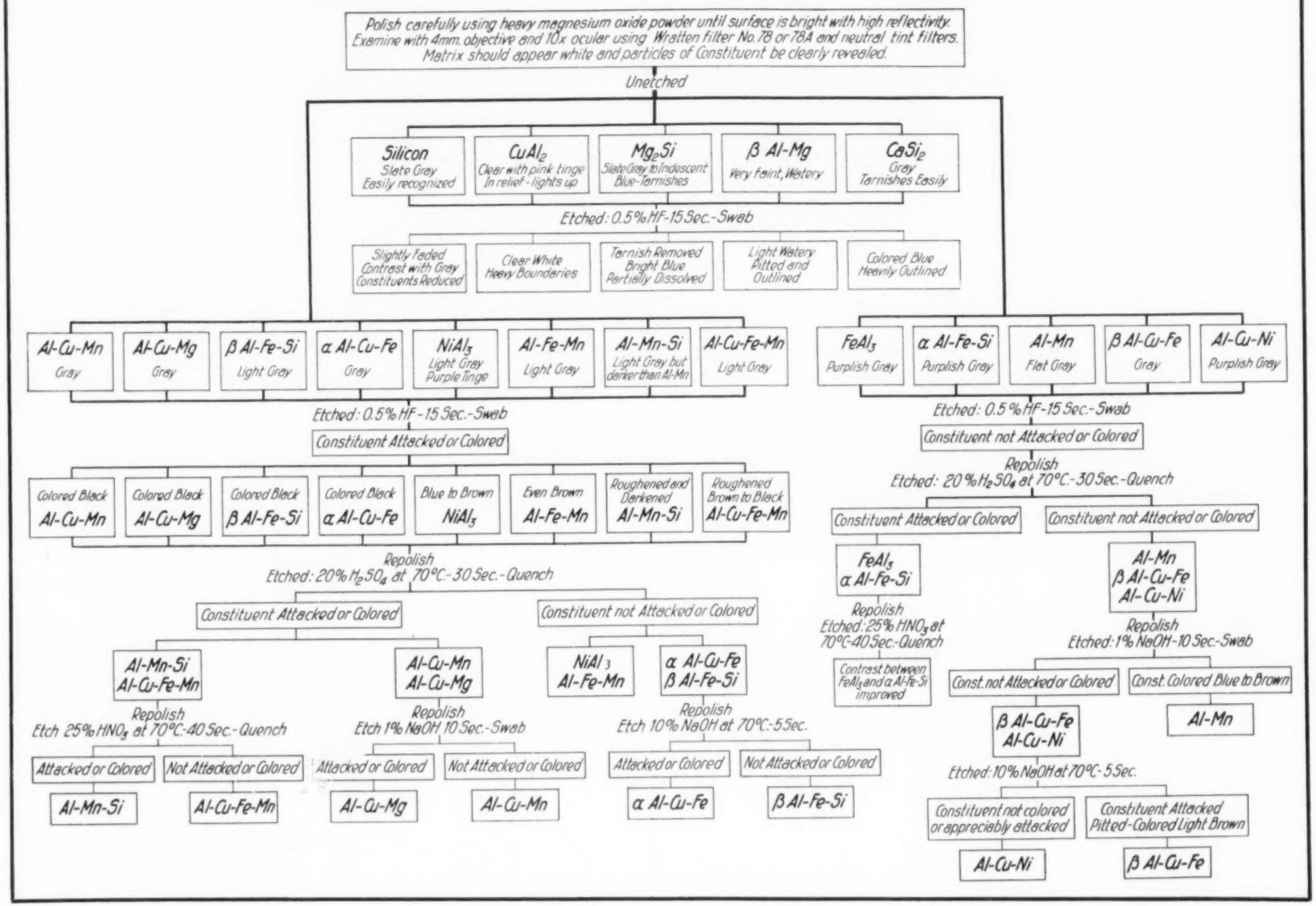
Aluminum beer barrels, which were introduced on a modest scale a few years ago, are now established firmly in the brewing industry and are being produced literally by the thousands. The success of this barrel when used for the transportation of other liquids has more recently resulted in the design and marketing of an aluminum carboy.

Several of the alloys formulated several years ago have become more firmly established with the trade and have permitted the use of light alloys in new fields. For example, marine applications were for years restricted by the fear of the susceptibility of the available structural alloys to salt water corrosion. Now, however, alloys of adequate strength and high resistance to corrosion are being used to an increasingly greater extent. The construction of all-aluminum racing and pleasure boats already has been undertaken on an experimental scale and it seems entirely possible that light alloys will be used to a large extent in future craft of these types.

Aluminum alloys have retained their important position in aircraft and have contributed substantially to the recent spectacular

Identification of Constituents in Commercial Aluminum Alloys

By F. Keller and G. W. Wilcox, Aluminum Research Laboratories (After Dix and Keith, with additions)



accomplishments of that industry. With regular transatlantic passenger and mail service already established, and stratosphere flying proposed for the near future, the demands upon the structural materials and power plants undoubtedly will become still more exacting. To meet these and other rigorous requirements by active investigation of new alloys and processes increased facilities for research and development are necessary. The Aluminum Research Laboratories' buildings are even now being enlarged by the construction of two new wings; one to house one of the most powerful testing machines in the world, the other to furnish space for additional offices and laboratories.

Manufacturing facilities are also being expanded. A new plant for the processing of raw bauxite has been completed in Mobile and several of the reduction plants have been expanded. Extrusion plant facilities were expanded by the construction of a new mill at Lafayette (Ind.), while additional casting and forging capacity was provided by a new plant in Los Angeles.

Electrolytic Manganese and Its Alloys

By R. S. Dean, Chief Engineer,
Metallurgical Division, Bureau of Mines,
U. S. Department of the Interior
Salt Lake City, Utah

COMMERCIAL PRODUCTION of a metal having a purity of 99.98% is always of interest. When that metal is one of the few really plentiful metals in the earth's crust — namely manganese — it would seem that something of major importance has been accomplished.

The electrolytic preparation of metallic manganese, announced two years ago by the Bureau of Mines, has been improved and commercial production begun at Knoxville, Tenn., by the Electro Manganese Corporation. While the amount of material yet available is relatively small and the price necessarily high, there have been no developments which would indicate that with really large-scale production electrolytic manganese cannot be produced at a price in the same range as copper or zinc and considerably below that of nickel. When such costs are reached there are many obvious uses for this pure metal in the steel industry, which now consumes nearly all of the manganese.

Of more metallurgical interest, however, is the value of this manganese as a base metal for non-ferrous alloys. While the pure manganese itself is brittle, it can be readily made highly ductile by alloying with less than 3% of certain elements; for example, 2% copper and 1% nickel. Such a slightly alloyed manganese can be drawn into fine wire and worked in any other way desirable. Cold-worked material has a tensile strength of 150,000 psi., and may be greatly hardened by suitable heat treatment. Since the modulus of elasticity of gamma manganese is of the order of 20,000,000 psi., it will be seen that high rigidity can be obtained with suitable dispersion hardening.

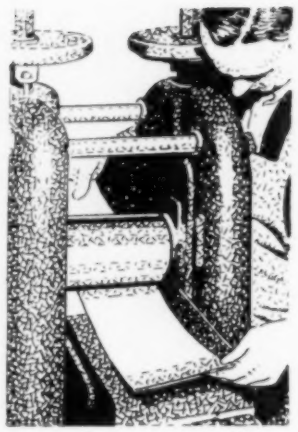
Of perhaps greater engineering interest is the fact that many alloys high in manganese — such as the 90% manganese, 10% copper alloy — have an exceptionally high vibration damping capacity, exceeding 10% for very small applied stresses. The possibilities of such material in spring suspensions and other machine elements will be at once apparent. All of these alloys are capable of heat treatment to develop a great variety of properties.

The new manganese also enters ductile alloys with copper and nickel, and copper and zinc, having very much higher manganese than has heretofore been possible. Almost the entire range of copper-nickel-manganese alloys are ductile; and the alloys containing 75% or more manganese which could not be satisfactorily made with the alumino-thermic material promise to have the most interesting properties of the entire group — namely, a very high coefficient of linear expansion, reaching 28×10^{-6} cm. per cm. per °C.; electrical resistance of nearly 200 ohms per $cm.^3$, and a zero temperature coefficient of electrical resistance. Alloys of this series containing somewhat less manganese are highly corrosion resistant and have physical properties at least as good as those of nickel silver.

The manganese-copper-zinc alloys in the high manganese and relatively low zinc contents have essentially the properties of alpha brass, but the color of nickel silver. Alloys containing 65% or 70% zinc, 20% manganese, and the balance copper, give excellent high strength castings and should be attractive on account of their cheapness.

Electrolytic manganese alloys with aluminum in an entirely different manner than the silico-thermic or alumino-thermic metal. As is well known, more than 2% of manganese added

to aluminum produces a coarsely crystalline structure with comparatively little ductility. By the use of high purity aluminum with electrolytic manganese this coarsely crystalline structure is not obtained until more than 7 or 8% of manganese is added. Since manganese is a most desirable hardener for aluminum from a corrosion standpoint, the ability to increase the hardness of aluminum by the addition of manganese alone should prove of value.



Finally I must mention the exceedingly interesting alloys of iron, chromium, and manganese. When these alloys are prepared from pure materials highly ductile alloys may be obtained which are hardenable by a quenching and re-heating process, and which retain a high degree of stainlessness in the hardened condition. A typical alloy of this class contains 18% chromium, 25% manganese, and the balance iron.

As the properties of manganese alloys made with pure manganese are re-investigated it seems highly probable that a large number of useful alloys will be found. As a base metal for alloying purposes manganese has several basic advantages: A relatively high melting point; a higher modulus of elasticity than other non-ferrous metals; several allotropic transformations which permit the development of heat treatable alloys; and most important of all, the possibility of eventual production at a low cost.

Silver, a Commodity

By Lawrence Addicks
Bel Air, Maryland

SILVER finds itself at the crossroads and prediction as to its future calls for prophetic gifts. The controversial "16 to 1" of history has spread to 100 to 1 and, short of the exigencies of war financing, we are dealing with a *commodity*, pure and simple. Those who sell it are well aware of this and its future status depends upon how quickly those who might buy it acquire an appreciation of the fact that they have to deal with a noble rather than a precious metal. Meanwhile the U.S. Treasury continues to hold a somewhat leaky umbrella over the situation, devoutly hoping the weather may clear!

We therefore start with the price of silver in August 1939 at one-sixth of its former value in terms of gold, and the obvious necessity of greatly expanding its industrial use. The systematic search for uses which has been sponsored by associated producers for several years past, has resulted in convincing this observer, at least, that a solution lies right at hand in applying what we already know about the properties of the pure metal.

Silver has been used chiefly for the photochemical response of the halide salts, as an optical reflector and as a jeweler's stock in trade, with electrical contacts and brazing alloys as recent additions. This is a poor showing when we consider that it has great resistance to oxidation, is unattacked by organic acids or strong alkalis, has unapproached electrical and thermal conductivities, very high reflectivity for most wave lengths, and fungicidal and bactericidal properties — to give but a partial catalog.

This, certainly, is quite a bag of tricks, wherefore a systematic campaign of developing methods of forming *non-porous* silver coatings on metals, plastics, glass, paper, and other materials has been coupled with a series of comparative tests with competitive linings now used in tanks, vessels, bottles, cans, and containers of all sorts, many of which are admittedly lacking in one or another desired characteristic.

A great deal of work is underway in technical laboratories throughout the country, much of it stimulated by the subsidized research already referred to, but some of it quite independent thereof — as in the recent work on silver in stainless steels. A number of companies are working on silver bearings, certain alloys are under scrutiny, special coating methods are being developed. My personal view is that silver as an industrial metal is headed toward a large development and that the future peace of mind of the silver producer is very closely bound up with the accuracy of this prediction.

If the foregoing seems a little sketchy, it is because the Editor of METAL PROGRESS is a master of epitome. He is quite capable of asking for 150 words on the influence of the Koran on the present development of religious thought in Egypt!

HEAT TREATING & FINISHING

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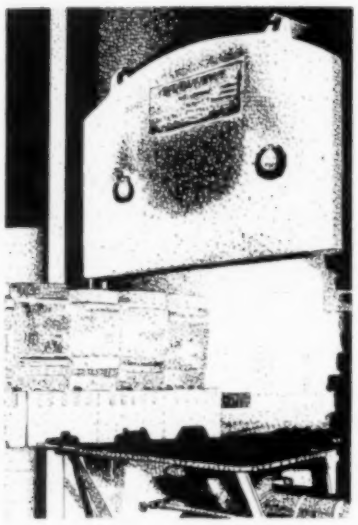


Heat Treating and Finishing

Heat Treating for Machinability

By A. L. Boegehold
Head, Metallurgy Dept.
General Motors Research Laboratories
Detroit

IN MACHINING rear axle ring gears and pinions, it is desired to condition the steel so that not only will machining be most economical but a fine finish obtained. The fine finish is necessary because no further finishing is done after hardening. The quality of the surface has an influence on the quietness of the gear and upon its durability.

A few years ago difficulty was experienced, particularly with the nickel-molybdenum type of carburizing steel, because of the presence of hard spots created during ordinary normalizing (a gradual cooling through the lower critical temperature). These hard spots proved to be small regions of martensite; carbon and possibly nickel and molybdenum segregation increased the hardenability in these spots to the extent that transformation was suppressed even by air cooling after furnace cooling down to 1200° F. This segregation of carbon and alloy occurred during furnace cooling through most of the transformation range. The cure for this was found to be a special annealing cycle, consisting of cooling rapidly through the Ar_3 by transferring from the high temperature furnace to one at 800° F., and holding at that temperature. Cooling through the transformation range in this way retards migration of carbon to localized bands in those steels prone to this tendency. Those heats of steel having less tendency to form the banded structure require no special annealing treatment to prevent the occurrence of hard spots.

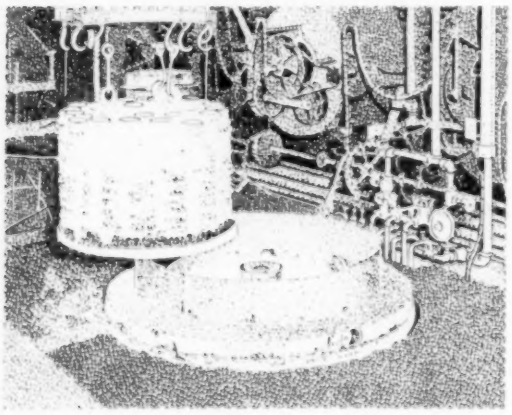
Complete prevention of banding, insuring a homogeneous structure, could be accomplished by including a salt bath quench at about 1200° F. as a part of the normalizing cycle. Such a cycle would begin by heating to 1750 to 1800° F. for the purpose of obtaining a coarse grain size, followed by cooling to about 1425° F. (which is slightly above Ar_3) at which time the structure would consist entirely of austenite free from any carbon segregation. At this point the forgings would be quenched in a liquid salt bath at a temperature where isothermal transformation would yield a type of structure most desired for good machining. The rapid cooling through the transformation range as a result of the quench in salt would completely prevent any carbon segregation and then isothermal transformation at a suitable temperature would yield the type of structure found best suited for machining purposes. The pronounced difference between the structures obtained by holding at 1200° F. after furnace cooling in one case

and salt quenching in the other is due to the fact that in the former, constant temperature transformation occurs in microscopic patches of high carbon steel, while in the latter case the carbon is uniformly distributed.

Many variations of this cycle could vary the final microstructure. As an example, after immersing the forgings in one end of a long salt bath they could be moved toward the other end (maintained at a higher temperature) at a rate that would cause the transformation to begin at 1200° F. or lower in order to get an adequately rapid quench and progress toward some higher temperature in order to get the desired austenite decomposition products.

Pursuing the idea of annealing by means of a salt bath still further, yields the thought that the normalizing furnace could be eliminated by placing hot forgings, immediately on completion of forging and trimming, into a salt bath held in the neighborhood of 1200° F. The coarse grain size as a result of the forging temperature would be ideal for easy machining, the rapid cooling to 1200° F. would prevent any ferrite banding, and the transformation at constant temperature would dispose the carbides in the form desired for easy machining. The important advantage gained would be the fine dispersion of ferrite, favorable to a smooth finish in the machining operation. The exact details of such a process for obtaining the desired machining characteristics could not at present be prescribed but the possibilities appear favorable enough to warrant careful investigation.

Processing of large quantities of forgings in this manner would probably require that the salt bath, in addition to having heat supplied to it for bringing it to temperature, would have cooling coils to remove the heat introduced by the hot forgings.



Heat Treatment of Tools

By S. C. Spalding
Metallurgical Engineer
The American Brass Co., Waterbury, Conn.

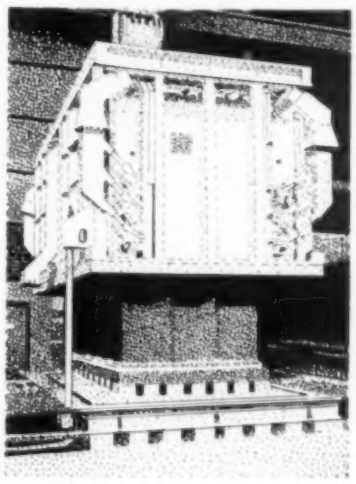
TOOL HARDENING, a more familiar term than the heat treatment of tools, requires means of heating of the tool and means for cooling (usually termed "quenching after heating") then a second reheating for tempering (or, as more commonly known, "drawing"). In the early days these facilities could be pretty well described by the blacksmith's term "fire and water". In recent years there has been developed very specialized pieces of equipment for these operations and it is some aspects of these as they now exist and may be cautiously predicted in the future that I will mention here.

For the second operation, cooling, we have the various standard mediums such as water and water solutions (brine and sodium hydroxide), oils, molten baths of salt or lead, and finally, air — either still air or an air blast. The properties of these various mediums have been rather thoroughly investigated and they are applied as suits the tool to be treated. The development of satisfactory means for the *third* step, tempering, while stagnated for many years to heating on a hot plate or before the open door of a furnace, has in quite recent times been well taken care of. We have available all types of liquid baths — oil, salt or lead — with fuels whether electricity, gas or oil, automatically controlled so as to maintain almost absolutely uniform temperatures with no attention required from the operator other than the setting of the mechanism and charging and discharging the work. We also have oven or retort type convection furnaces with forced circulation of atmosphere, all very accurately controlled.

I have left mention of the first operation of heating the tool till last, for this reason: While great strides have been made in types of furnaces and equipment for uniform heating of the tool, another very important part of the operation, protection of the surface of the tool during heating, has only fairly recently received very widespread consideration. It has now been recognized, however, as the very crux of the situation, as illustrated by the increasing number of technical papers presented at our convention gatherings and to local groups on furnace atmospheres, so-called "controlled atmospheres", their means of production and control and the effect upon tools. Attendance at the

Metal Shows from year to year cannot fail to show the increasing number of displays of equipment for hardening in controlled atmospheres, and its constant improvement. One can today, if his ear is to the ground, even hear whispered the words "bright hardening".

Devices for approaching this condition are numerous and varied in method. The progress toward the development of inert or strictly neutral atmospheres has been substantial so that the writer feels confident the time is not far distant when "bright hardening" will be an accomplished commercial process and we will no longer be constrained to grind, pickle, polish, blast, or what have you, to remove the damaged surface put on our carefully made tool in the heating furnace, and put it into such shape it is fit to use.



This I feel is our major problem in the heat treatment of tools and is nearer final solution today than ever before. Who knows what additional properties and performance we may expect from tools which have been "bright hardened"?

Atmospheres for Scale-Free Hardening

By Robert B. Schenck
Chief Metallurgical Engineer
Buick Motor Division, General Motors Corp.
Flint, Mich.

THE DESIRABILITY of scale-free hardening has received increasing recognition in the past few years with the result that equipment is now available for the commercial production of furnace atmospheres which can be controlled with a high degree of accuracy.

Furnace atmospheres for hardening steel cover a range from scaling to carburizing, considering these effects as the two extremes. In scale-free hardening the atmosphere may be either carburizing, decarburizing or neutral to the particular steel being processed. The requirements of the job will in each case determine the type of atmosphere to be used.

Neglecting for the moment the effect of alloying elements and impurities in the steel, any atmosphere capable of carburizing will be in equilibrium with a steel of some definite carbon content at any given temperature. Thus, a prepared gas may be in equilibrium with a 0.45% carbon steel at 1500° F., yet it would decarburize steels with higher carbon and carburize those with lower carbon, the tendency being to adjust the surface carbon concentration on higher or lower carbon steels to the equilibrium point of 0.45%.

These conditions of equilibrium change with gas composition, temperature, carbon content of the steel and other elements in the steel. Silicon tends to lower the carbon equilibrium point and manganese tends to raise it. The normal impurities usually present in steel have no appreciable effect. It follows that the same gas may carburize under one set of conditions and decarburize under another, or it may be neutral and leave the surface carbon of the steel unaffected. It is difficult, therefore, to do more than cite specific conditions that have given satisfaction.

The general principle underlying the manufacture of most of the commercial gases for scale-free hardening involves the partial combustion of fuel gas with the production of hydrogen, carbon monoxide, carbon dioxide, water vapor, nitrogen and a small amount of hydrocarbons. The requirements to be met determine the additional processing the gas must receive with respect to the removal of detrimental components, mainly moisture and carbon dioxide.

A recent development, in which partially burned fuel gas is processed to nearly pure nitrogen (99.8 N_2), is now available for work which justifies the expense of such an atmosphere. The 0.2% of gas other than nitrogen may be either CO or O_2, and it is claimed that the composition can be controlled so as to be definitely on one side or the other. Some engineers prefer a mixture of more active gases, in the sense that enough carbon should be present to render innocuous the oxygen and moisture unavoidably carried into the furnace with the work when it enters.

The physical chemistry involved in the reactions between mixed gases and steel at high temperatures is exceedingly complex and until recently was little understood. Due to the

increasing demands of industry, this subject is now receiving intensive study and rapid progress is being made in the development of equipment for the production of economical and efficient protective atmospheres.

Heat Transfer Processing
in pre-formed atmospheres

By Floyd E. Harris
Furnace Engineer, Buick Motor Division
General Motors Corp., Flint, Mich.

MODERN HEAT TREATING involves the provision of means for heating the steel to temperatures of 1350° F. and above without surface change. Time, temperature and atmosphere composition are factors controlling the steel surface condition.

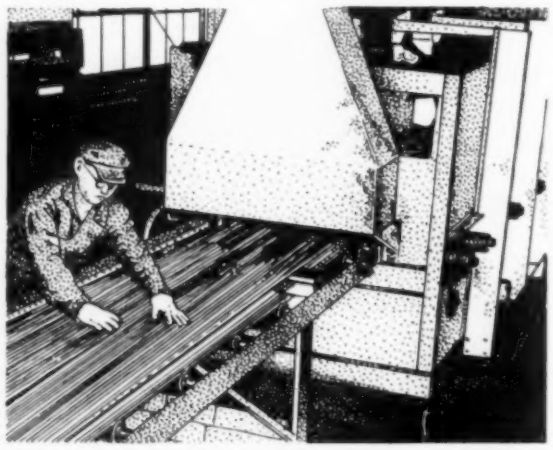
With extremely fast heating and very short time at temperature (induction heating of surface layers, for example) the composition of the steel surface is found to be unchanged, regardless of the nature of the atmosphere. *Time* is therefore one of the controlling factors in today's heating practice. As the time at temperature is increased, the atmosphere composition must be nearer and nearer that which will be in equilibrium with the composition desired at the steel surface.

Atmosphere control will be comparatively simple for a low carbon steel like sheet steel, or, on the other hand, where the carbon content desired is the maximum in solution at the temperature employed — as is the general case in carburizing. Thus, for low carbon steel, a highly reducing condition will prevent oxidation, while for carburizing, excessive strength of carburizing gases is limited by the ability of steel to absorb carbon at a given furnace temperature.

In systematizing this study of heat transfer processing in prepared atmospheres, the writer has found this view useful: At any given temperature the gas composition for a desired steel surface will be determined by its "carbon activity". The activity of solid graphite may be taken as unity, corresponding very closely to that of saturated austenite. Unsaturated solutions of carbon and iron will have an activity equal to some fraction of that of saturated austenite. Practically complete absence of carbon (ingot iron) would be represented by zero activity. Thus gases in equilibrium with graphite will, for the same temperature, also be in equilibrium with steel having a carbon content close to that of saturated austenite, and will carburize steels of all carbon contents of lower activity, just as gases in equilibrium with low carbon contents will decarburize carbon contents of higher activity. Between zero and unit activity, each carbon content will have, as pointed out in Mr. Schenck's note on "Atmospheres for Scale-Free Hardening", page 369, a definite gas composition in equilibrium at a given temperature, and this composition for a given carbon content will vary with the temperature employed. (These remarks apply principally above Ac_3.)

The preparation, control and application of commonly available fuel gases and their combustion products for approximate equilibrium with intermediate carbon activities at temperatures above 1350° F. is, then, a very special problem. (A simpler way to state it is, perhaps, that a furnace atmosphere that will neither scale, carburize nor decarburize hot steel at 1400° F. is quite different from an atmosphere truly neutral to the same steel at 1600° F.) Preliminary equilibrium of the gas atmosphere with some form of carbon (for example, charcoal) is offered as a practical solution, in the form of an auxiliary reaction chamber, preferably as an extension of the processing muffle, but under separate temperature control.

In such a device, gas will be supplied to the auxiliary chamber from a charcoal generator, whose final temperature will be well above that of the steel. This gas after traversing the hot charcoal will be practically free from water vapor and carbon dioxide, have only a trace of methane, and will consist mainly of hydrogen, carbon monoxide and nitrogen. Charcoal in the generator is maintained at a high temperature to insure a close approach to equilibrium in the reactions of re-forming the raw air-gas mixtures. Liberal provisions for



heating are needed, due to the endothermic character of the reactions involved.

The auxiliary reaction chamber will therefore be controlled at that temperature at which the prepared gas in equilibrium with charcoal will give an atmosphere in equilibrium with the surface carbon desired in the steel being processed. As most of the gas reactions with the charcoal will be exothermic, this condition should be easily attained.

This scheme of operations, then, will accomplish the fixation of the processing gases in the presence of solid carbon in a separate chamber adjacent to that containing the steel being processed. Not the least advantage from this arrangement will be that the gases enter the chamber containing the steel at almost the correct temperature of the processed stock. This point will be readily appreciated by all who recognize the rapid change, with temperature, of equilibrium compositions of the mixed gases.

Induction Hardening
in automotive production

By William H. Graves
Chief Metallurgist
Packard Motor Car Co., Detroit

THIS PAST YEAR has seen further extension of the process of induction heating for localized surface hardening to various articles. It is coming into more general use because of its control and flexibility. Shape and depth of hardness are controllable, the metallurgical structure of core, demarcation zone and hardened case may be varied and controlled. Another most desirable feature is the practical lack of distortion and scale formation. Hardening equipment is of a design that is readily adaptable to production line requirements, both as to space required and location, together with automatic regulation of power and split-second heating and quenching which are necessary to the process and make for uniformity of results.

Induction hardening equipment allows the user to

(a) Surface harden only the requisite portion and at the same time maintain the original ductility and strength at other places.

(b) Harden or anneal articles of intricate design which cannot be feasibly heat treated in other known ways.

(c) Eliminate costly pre-treatments such as carburizing or copper plating, and subsequent treatments such as straightening or cleaning.

(d) Cut down the material cost by permitting a wider selection of steels.

(e) Be able to harden fully machined parts without the necessity of further finishing.

Induction hardening is now done on many important parts. One of the earliest applications was to the bearing surfaces of crankshafts. These are hardened up to the fillets to Rockwell C-60, leaving the core and fillets with their original structure, and with a gradual transition of structure from the hardened to the unhardened sections. Packard Motor Car Co. hardens pearlitic malleable camshafts at the rate of 60 complete shafts an hour with one operator. The surface of the 12 cams and the eccentric are Rockwell C-60 and the integral oil pump gear is Rockwell C-55. Likewise 125 transmission shafts an hour are processed with three areas hardened, each to a different specified hardness within the range Rockwell C-50 to C-60.

Axle shafts are strengthened by eliminating the inner bearing roller race which was pressed on each shaft, necessitating a corresponding decrease of cross sectional area. An annular area was hardened to Rockwell C-62 at the desired location permitting the axle shaft itself to act as the race for the bearing. One induction hardening machine handles 500 axle shafts per hour.

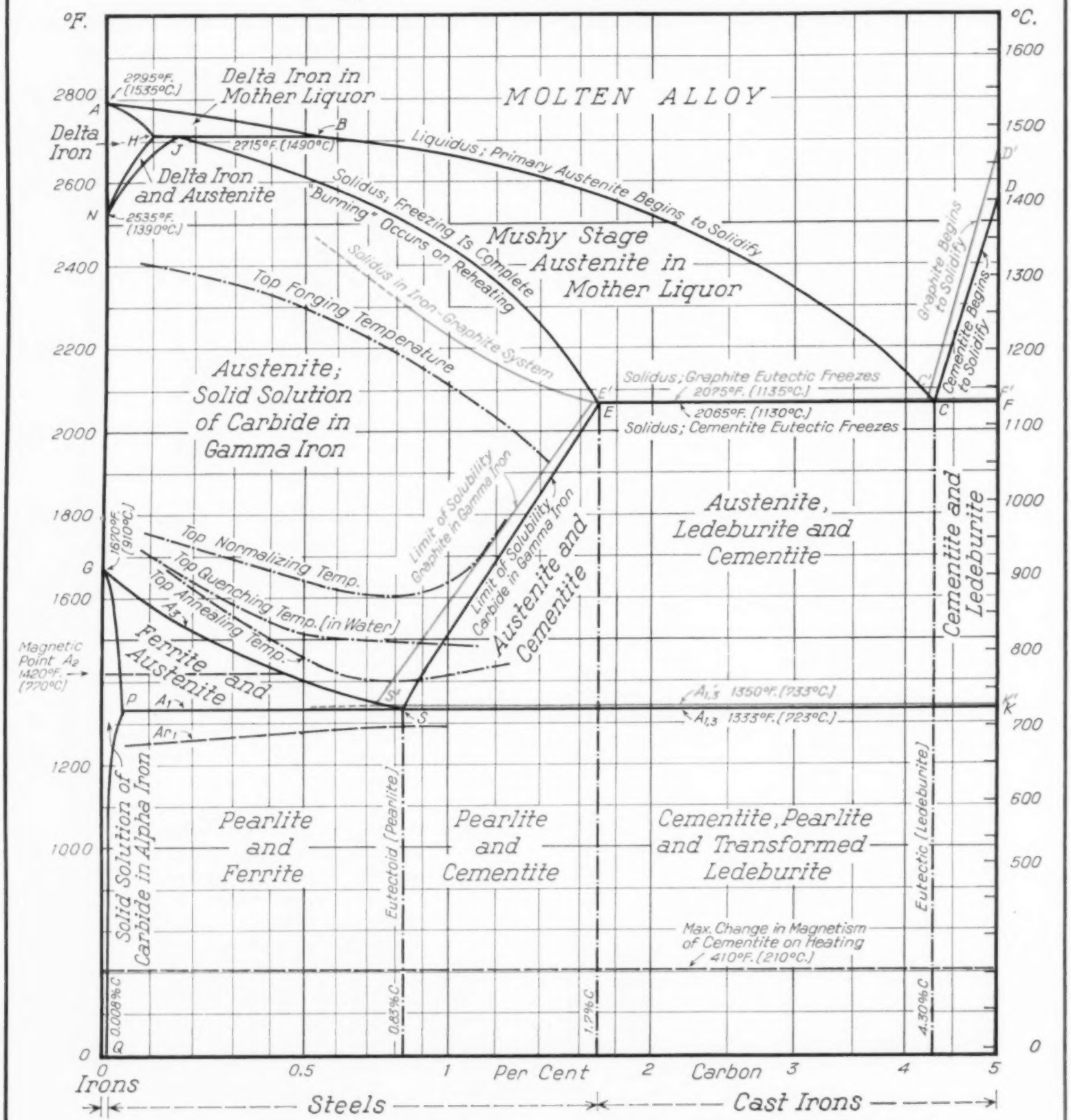
Push rod seats for automobile tappets are hardened with magazine feed at the rate of 5000 per hour with a Rockwell C-50 minimum. Wrenches, hammer heads, pliers, screw drivers and numerous other tools, taps and dies, drills, sprocket shafts, tractor track pins, starter shafts, rotor shafts, studs, and a multiplicity of camshafts and other parts of varying design are produced with the correct surface areas hardened to the desired degree and depth.

A small section of a previously hardened object can be drawn to a condition permitting ready machinability, and even more unique is one application which surface hardens a piece of steel and at the same time copper-brazes it to another part.

In summing up, induction hardening offers the following important advantages: *(a)* Hardening or annealing certain parts not otherwise heat treatable in production. *(b)* Improved hardening with lower cost materials. *(c)* Improvement in design giving better quality or lower cost. *(d)* Lower production costs with equal or better quality.

Iron, Iron Carbide Equilibrium Diagram

Approximate Iron-Graphite Diagram in Red



Except as noted hereafter, lines are reproduced by courtesy of The Engineering Foundation from diagrams published in one of the Alloys of Iron Monographs: "Alloys of Iron and Carbon," Vol. I on Constitution, by Samuel Epstein.

Delta iron region and solidus by Frank Adcock, *Journal* of the Iron and Steel Institute, 1937-I.

Forging and heat treating temperatures from Recommended Practices, 1939 ASM Metals Handbook.

Solidus in Iron-Graphite System according to Kaya, Honda and Endo, *Science Reports*, Tohoku Imperial University, 1925 and 1927.

Ar_1 according to Hoyt and Dowdell, "Metals and Common Alloys," for cooling rates of 1° C. in 3 sec.

Line GPQ according to J. H. Whiteley, *Journal*, Iron and Steel Institute, 1936.

Solidus in graphite system left of E′ as suggested by Harry A. Schwartz.

Induction Heating
for diversified heat treatments

By L. C. Conradi
Technical Research Director
International Business Machines Corp.
Endicott, N. Y.

A YEAR AGO it was stated in this magazine that heat treatment by high frequency induction was in its infancy. This statement is true today with even greater emphasis. There has been a steady increase in the application of this process and the design of the equipment, and its use in the future is bound to grow by leaps and bounds.

More industries have become familiar with the possibilities of this new method of localized heating for purposes of hardening. As was to be expected, the automotive industry has found this process ideal because the equipment can be readily mechanized, making the actual heat treating operation either semi-automatic or fully automatic. Furthermore, irrespective of by what means the high frequency current is generated, a unit can be readily placed into existing production lines and will occupy less space than the conventional furnace equipment which it replaces.

However extensive the application of high frequency induction heating is and will be in the automotive industry, I look for even greater adoption of this process by the rank and file of the machinery manufacturing, tool making, metal working, and metal using industries throughout this country. In these industries the question of mass production of standardized parts is not as important as the ability to handle both rapidly and economically a great variety of different parts. In these industries, heat treatment by high frequency induction will largely revolutionize and replace present heat treating practices. We are finding that this is the undoubted trend in the manufacture of modern business machines.

The outstanding advantages of heat treatment by high frequency induction may be summarized thus:

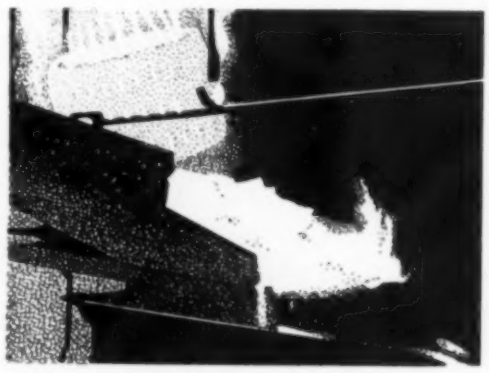
1. Heating and hardening can be localized with great precision.

2. Copper plating and claying for purposes of selective carburizing and hardening can be largely eliminated, thus facilitating subsequent machining operations during assembly.

3. Carburizing operations can frequently be eliminated by using either carbon or alloy steel capable of hardening on direct quench. In this manner, for all practical purposes the benefits of a hard case supported by a tough core can be realized without resorting to carburizing operations.

4. Flexibility of the process is such that it can be readily adapted to hand or full automatic operation.

5. Since heating is so rapid, cleanliness of the hardened work compares favorably with the conventional scale-free and clean hardening methods.



the scientific aspect of
Hardening Steel

By Alvin J. Herzig
Climax Molybdenum Co. of Michigan
Detroit

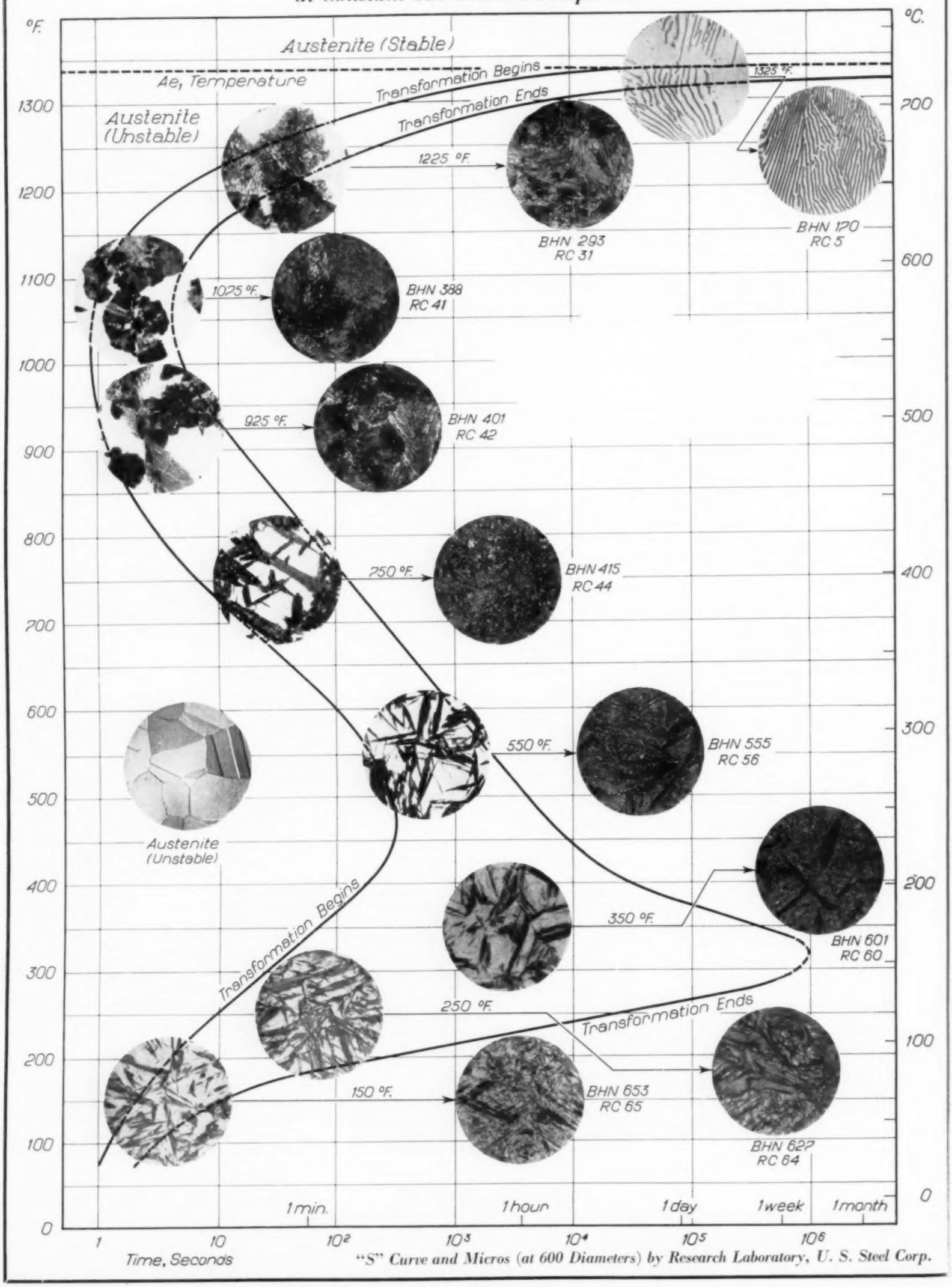
AN EARLY scientific aspect of the hardening of steel is expressed in the following quotation from the naturalist and mathematician, Cardanus, a quotation which indicates the state of the knowledge of hardening steel in 1557: "Steel is nobler than iron, and exists in two forms, as made steel and native steel . . . . When it is well cleaned, and then heated, and quenched three or four times in equal parts of extract of radishes and water which had contained earth worms, it cuts iron like lead."

All of the phenomena attending the hardening of the piece of steel used by Cardanus have been carefully observed for several centuries. As we recall the tremendous efforts that were made periodically to conceive a hardening theory consistent with the large amount of observational data, it is interesting to review the relatively few facts essential to our present understanding of the mechanism of hardening.

The first important fact was the determination of the critical points in iron. This determination was made by Osmond using the Le Chatelier pyrometer. Swedish and Russian investigators had known and published some facts about critical points long before.

Transformation of Austenite in 0.78% Carbon Steel

at Constant Sub-Critical Temperature



"S" Curve and Micros (at 600 Diameters) by Research Laboratory, U. S. Steel Corp.

The value of this clue was known to Charpy in 1895 who believed that the hardening of steel depended on the suppression of the "Osmond transformations" by rapid cooling.

Then followed a period of several years in which, by means of the microscope, Sauveur, Osmond, and Behrens correlated the thermal treatment of steel with the resultant microstructure. In this period, ending about 1900, the microconstituents pearlite, ferrite, cementite, martensite and austenite were identified and named, and the iron-carbon equilibrium diagram had been coordinated by Roozeboom adequately enough to be useful to metallurgical research.

The theorizing done in this period led largely in the wrong direction despite the statement of Le Chatelier in 1897 that "the speed of the transformation taking place during the recalescence is regulated principally by the temperature . . . ."

The next fundamental contribution came through the application of the X-ray. During 1917, 1918 and 1919 Hull studied the crystal structure of iron at room temperature and concluded that its atomic arrangement was body-centered cubic. In 1921 Westgren and Lindh determined that austenite was face-centered cubic. In 1926 Fink and Campbell discovered the body-centered tetragonal structure in freshly quenched martensite which had been anticipated by Bain in 1924.

Finally in 1930 Davenport and Bain, by using the sub-critical isothermal technique to study the transformation of austenite, showed conclusively that the nature of the product of austenite decomposition and the rate of decomposition are dependent directly upon the temperature at which transformation takes place.

So it is that today we may describe the mechanism of the hardening of steel in considerable detail based on the established facts mentioned above.

The polymorphism of iron is of such nature that it confers on iron-carbon alloys a reaction capable of developing diverse products having a wide range of useful properties. It is comparatively recently that we acquired a knowledge of the factors enabling us to control this reaction intelligently and obtain at will the products desired. But, equally important to the metallurgist, that knowledge has given us an understanding of the hardening of steel that seems crystal clear compared to our ideas of a few years ago.

Austempering

By E. S. Davenport
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United States Steel Corp., Kearny, N. J.

THE HEAT TREATING process which goes by the name of "austempering" is now so well known as scarcely to need definition. In principle, it is the method of heat treating steel involving the direct, isothermal transformation of austenite to the final structure at temperature levels between the pearlite-forming and martensite-forming ranges of temperature. By austempering, relatively high values of hardness (Rockwell C-50 to C-60), accompanied by a remarkable degree of toughness and ductility, may be obtained in carbon and in certain moderately alloyed steels. A working knowledge of the appropriate isothermal transformation diagram (such as the "S" curve for high carbon steel shown on page 374) is necessary for the intelligent application of the process to a steel of given composition and austenite grain size.

Interest in the process and the results which may be achieved by it is rapidly increasing, as shown by the number of articles dealing with different aspects of the subject which have appeared in technical journals and periodicals within the past two or three years. The most recent of these articles describe the application of the process on a commercial scale.

The early investigations were confined largely to carbon steels of relatively high carbon content, 0.60% or higher. Within the size limitations dictated by the "S" curve and hardenability of such steels, the combination of properties obtained was so striking that it was only natural to inquire whether the process could be applied with equal success to some of the common alloy steels. This question is now being actively investigated, as evidenced by the published results of Payson and Hodapp, Griffiths, Pfeil and Allen, and of Legge; additional information along these lines, as yet unpublished, is rapidly accumulating and the whole problem of alloy steel austempering is in a state of active development and orientation. Certain alloy steels show about the same order of improvement in mechanical properties, especially when austempered to the higher hardness ranges, as do the plain carbon steels. Many of the comparisons published to date have been made at hardness levels too low to warrant any reasonable hope of benefit from austempering.

The teachings of isothermal transformation studies indicate that alloy steels should be austemperable in much heavier sections than carbon steels and this has been substantiated by experiment. Applications to alloy steels require the isothermal transformation diagrams for these steels; such diagrams are rapidly becoming available, but there is much spade work yet to be done.

It is obvious that the benefits to be derived from the austempering of alloy steels would have to be positive and substantial to justify the cost of a lengthy heat treatment on top of the cost of these higher priced materials. However, there are encouraging indications that the austempering schedules for many of these alloy steels will not be nearly as protracted as it was at first thought they might be.

Clearly, it is far too early to draw final conclusions on the scope and limitations of this process. In some directions we have only begun to develop information which will ultimately lead to such conclusions. At the moment, carbon steel or moderately alloyed steel — both over 0.50% carbon — still hold the center of the stage, although further investigation will undoubtedly bring to light many examples of other new modifications of alloy steel which can be greatly benefited. In this writer's opinion, the future enlargement of the field with respect to alloy steels is dependent upon a broader knowledge of the isothermal transformation diagrams of these materials and a better understanding of the nature and properties of the acicular products of austenite transformation.

Precipitation Hardening

By Robert F. Mehl
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Department of Metallurgy
Carnegie Institute of Technology, Pittsburgh, Pa.

PRECIPITATION HARDENING — or age hardening — is by no means a new phenomenon. It might well be supposed, in the 27 years since the discovery of duralumin, that the development of age hardening alloys and the study of the process of age hardening would have reached a point of relatively slow progress, a sort of technological point of diminishing returns. Yet this is not true, for in many respects progress at the moment is more rapid than it has ever been.

From the engineering point of view it is somewhat strange that in early years so little attention was given to alloys of the heavy metals, for the higher strengths of heavy metals have from the beginning offered a promise of alloys of unusual properties. The alloys of copper and silicon, and of copper and beryllium have now become familiar commercial alloys; the recent reports on the high strength and fatigue resistance of alloys of nickel and beryllium are extremely encouraging — it would be pleasant to have more complete information on these alloys. Age hardening binary and ternary alloys of iron, tungsten, molybdenum and cobalt, studied so successfully by W. P. Sykes, the relatively recent modified monel metal, and the age hardening alloys of the precious metals, are examples of alloys in this class.

For some purposes such alloys are superior to heat treated steels of the martensite type. Perhaps one might well suppose that the further developments will occur chiefly among alloys such as these, for the possibilities in ternary, quaternary, and higher degree alloys are limitless and have hardly been reconnoitered. Systematic work is very time consuming; the orthodox method requires an initial determination of the full constitution of each polycomponent system — an impossible task, practically. A few guiding principles by which intelligent guesses of age hardening compositions might be made would be very welcome indeed. It is quite likely that progress in the practical field will be made by modification of alloys of compositions already known to be age hardening, and by chance encounter of alloys of other analyses.

We are apparently less than ever agreed

upon the nature of the precipitation process. A few years ago it was agreed necessary to assume some sort of a pre-precipitation process in order to account for the anomalous changes in electrical conductivity, in lattice parameter, in density, and in magnetic behavior. The recent work of Fink and Smith was an abrogation of this agreement! Whatever our opinion may be it must at the very least be admitted that their work discounts the lattice parameter anomaly, and throws doubt upon the polemic validity of the other anomalies. It appears to the writer that the safest conclusion to be made tentatively and for the present only (let the reviewer who passes judgment beware!) is that of Fink and Smith, namely, that the internal changes which give rise to age hardening originate in a process of true precipitation.

This is by no means generally accepted; perhaps the symposium at the fall ⊜ meeting may develop a reconciliation of divergent points of view, though one might more confidently predict that each debater will return home reaffirming to himself the correctness of his own view — that disease of the train which afflicts those who attend meetings.

It appears that the recent discovery of aggregates of solute atoms in the initial or low temperature stages of age hardening by Preston in England and Guinier in France is evidence for true precipitation, though it is almost certain that it will be taken by many as evidence for "complexes" or "knots". More evidence is needed on these Guinier-Preston zones, particularly for alloys other than duralumin; furthermore, additional studies are needed on transition lattices of the Θ' type in duralumin.

It seems a safe prediction that research in the near future will center around these two points, with further and more complete analyses of the geometry of lattice movements during nucleation — the so-called Widmanstätten mechanism — as this determines the incidence of such zones and transition lattices and less directly determines the unexpected changes in physical properties, long held anomalous.

Heat Treatment of Non-Ferrous Alloys

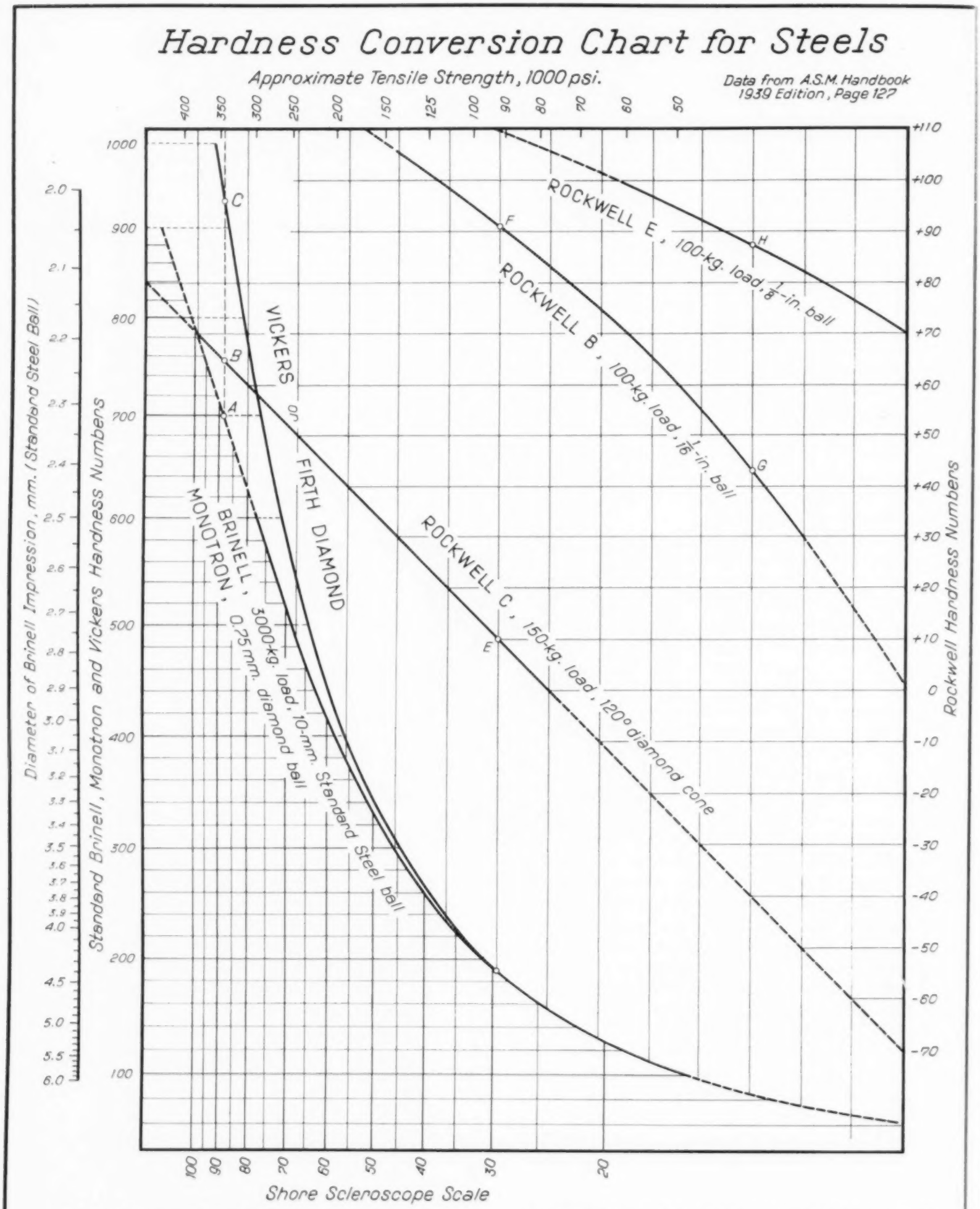
By Paul E. Petersen
Fuel Engineer, Chase Brass & Copper Co.
Waterbury, Conn.

IN SPITE of the rather radical changes in furnace design and heat treating practices during the last few years in the brass and copper field, the future should see considerable changes and improvements.

With the development and practical application of high temperature heat resisting alloys to the construction of fans, and their use in forced convection heating furnaces, there is a trend in some fields to go back to batch type annealing furnaces. Forced convection heating, with controlled direction high velocity gases, gives us extreme uniformity of temperature in the work annealed. For a number of years prior to the practical application of these fans, the trend was toward continuous furnaces of all kinds, primarily for this same purpose of obtaining better uniformity. The average brass sheet mill — because of the numerous alloys, gages, widths and desired tempers in the finished product — would prefer the flexibility of small batch furnaces. The indications are, therefore, that there should be a definite increase in the use of this type of furnace in the future.

Controlled atmosphere annealing has progressed in the non-ferrous field quite rapidly, but has not been exploited to full advantage. Copper in all its forms of sheet, wire, tube and rod, is being bright annealed in simple products of combustion from various gas fuels. Some of these atmospheres are the products of the combustion from the fuel used for heating, and others are prepared in special atmosphere generators auxiliary to the furnace. Although considerable work has been done with atmospheres for bright annealing or heat treatment of brasses and difficult copper alloys, their actual use on production units is quite limited. With the continued increase *(Turn to page 386)*

Hardness Conversion Chart for Steels



Verticals represent equivalent hardness.

For instance: Brinell or Monotron 700 (point A) equals Rockwell C-65 (point B), equals Vickers 930 (point C), equals Scleroscope 89 (bottom scale as modified by data from Westinghouse Research Laboratories), and about 340,000 psi. tensile (top scale).

Again: Rockwell B-91 (point F) equals C-10 (point E), equals Brinell, Monotron or Vickers 187 and Scleroscope 29, and has about 92,000 psi. tensile strength.

Finally, Rockwell B-43 (point G) equals E-87 (point H). Curve for latter scale is from Bureau of Standards Research Paper No. 185.

Data from A.S.M. Handbook 1939 Edition, Page 127

Hardness Conversion for Hardened Steels

By Howard Scott and T. H. Gray, Westinghouse Electric & Mfg. Co.

Diamond Pyramid Hardness 50-kg. Load	Rockwell Hardness: C-Scale-150kg. Brale Penetrator	Rockwell Hardness: A-Scale-60kg. Brale Penetrator	Rockwell Hardness: Superficial (From Wilson Mechanical Instrument Co. Chart No. 38) 15-N Scale	30-N Scale	45-N Scale	Scleroscope Hardness	Monotron Load Scale Value 19 Divisions	Brinell Hardness 10-mm. Ball, 3000-kg. Load: Hultgren Ball DPN 940 Hardness Number	Hultgren Ball DPN 940 Diameter in mm.	Steel Ball DPN 900 (From A.S.M. Metals Handbook, 1939 Ed., p. 113) Hardness Number	Steel Ball DPN 900 Diameter in mm.	Approximate Tensile Strength of Steel
DPH	R_C	R_A	15-N	30-N	45-N	Scl.	Mon.	BHN	mm.	BHN	mm.	$T.S. \times 10^3$
250	20	58	68	42	20	32	26	207	4.20	201	4.25	100
		60	70	44		34	28	212	4.15	207	4.20	
	25			46	24	36		217	4.10	212	4.15	
		62	72		26		30	223	4.05	217	4.10	
				48	28	38		229	4.00	223	4.05	
		64	74		30		32	235	3.95	229	4.00	110
300	30			50		40		241	3.90	235	3.95	
	32	66	76	52	32		34	248	3.85	241	3.90	
	34	67	77	54	34	42	36	255	3.80	248	3.85	120
350	36	68	78		36			262	3.75	255	3.80	
	38	69	79	56	38	44	38	269	3.70	262	3.75	
		70	80	58	40			277	3.65	269	3.70	130
	40				42	46	40	285	3.60	277	3.65	
400	42	71	81	60	44		42	293	3.55	285	3.60	
		72	82	62	46	48		302	3.50	293	3.55	140
	44	73	83	64	48	50	44	311	3.45	302	3.50	
450	46			65	50		46	321	3.40	311	3.45	150
		74	84	66	51	52	48	331	3.35	321	3.40	
	48	75		67	52	54	50	341	3.30	331	3.35	160
500	50		85	68	53	56	52	352	3.25	341	3.30	
		76	86	69	54	58	54	363	3.20	352	3.25	170
	52	77		70	55	60	56	375	3.15	363	3.20	
550	54	78	87	71	56	62	58	388	3.10	375	3.15	180
				72	57	64	60	401	3.05	388	3.10	190
	56	79	88	73	58	66	62	415	3.00	401	3.05	
600				74	59	68	64	429	2.95	415	3.00	200
	58	80	89	75	60	70	66	444	2.90	429	2.95	
		81	90	76	61	72	68	461	2.85	444	2.90	210
650	60		90.5	77	62	74	70	477	2.80	461	2.85	
	61	82	91	78	63	76	72	495	2.75	477	2.80	220
	62			79	64	78	74	514	2.70	495	2.75	
700	63	83	91.5	80	65	80	76	534	2.65	514	2.70	230
	64	83.5	92	81	66	82	78	555	2.60	534	2.65	
	65	84		82	67	84	80	578	2.55	555	2.60	240
750	66	84.5	92.5	83	68	86	82	603	2.50	578	2.55	
	67	85	93	84	69	88	84					250
				84.5	70	90	86					
800	68	85.5	93.5	85	71	92	88					260
	69	86		85.5	72	94	90					
850	70	86.5	94	86	73	96	92					270
	70.5				74	98	94					
900					75	100	96					280
					76	102	98					
950					76.5	104	100					290
					77	106	102					
1000					77.5	108	104					300
						110	106					
						112	108					310
						114	110					
						116	112					320

Thickness of Stock Required for Accuracy
(Ten Times the Depth of Impression in Inches)

DPH	DPH (10 kg)	DPH (50 kg)	R_C	15-N	45-N	BHN
200	0.017	0.038	0.072	0.015	0.040	0.186
300	0.014	0.031	0.059	0.012	0.032	0.135
400	0.012	0.027	0.050	0.009	0.026	0.098
500	0.011	0.024	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018-in. stock. Scleroscope numbers vary with size; relations given are for 1-in. pieces.

In operating any test machine, follow manufacturer's instructions and check frequently against test blocks. Major causes of discrepancy: *(a)* decarburized skin, *(b)* specimens too thin, *(c)* off-standard indenters, *(d)* inaccuracy of machine.

Above conversions are for steel, irrespective of composition and structure, up to its maximum hardness, and for any other material having about 30,000,000 psi. elastic modulus, uniform in depth to bottom of impression. (An exception is that Rockwell test values for shallow hardened steel may be 1 or 2 points higher than by conversion from DPH.) For sintered carbides (DPH 900 to 1700) with much higher modulus the relations between DPH and Rc may be computed from $DPH = \frac{2.445 \times 10^6}{(B - Rc)^2}$ wherein constant B is 118 for carbide (120 for steel).

corrosion protection of metals by

Cementation

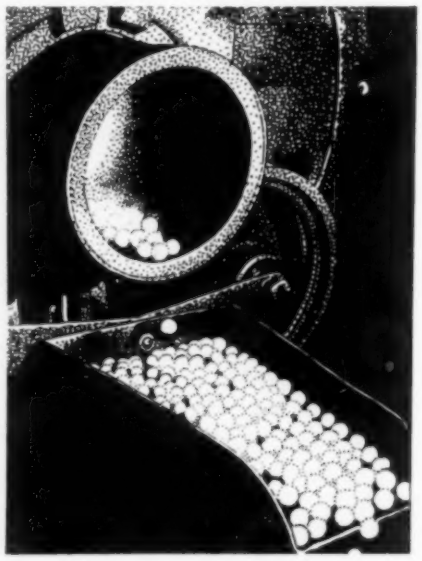
By Harry K. Ihrig
Director of Laboratories
Globe Steel Tubes Co., Milwaukee, Wis.

CORROSION is one of the serious problems of makers and users of metals. A very large tonnage of metal must be replaced each year because of corrosion. The increasing use of stainless steels and numerous non-ferrous, corrosion resistant alloys is an effort to solve this problem. However, some of these alloys have poor physical properties, some present fabrication difficulties, and all of them are high in price as compared with common steel. Therefore, they constitute only a small portion of the total tonnage of metals in use today.

Since metals are attacked only on their surfaces by corrosive agents, a base metal of common steel impregnated with an ennobling element would eliminate the difficulties experienced with the alloys mentioned above. The core would support the case and impart desirable properties to the article. The base metal could easily be fabricated, and, since the article would largely be made of common steel, it would be much lower in price.

For many years attempts have been made to impregnate metals with other elements to improve the properties of their surfaces, especially corrosion and wear resistance. In these experiments almost every element has been tried. Until recently, only impregnations with zinc and aluminum have reached commercial production. (Carbon and nitrogen cases are not included, because these impregnations do not offer substantial corrosion resistance and are not used for this purpose.)

There have been no new developments in recent years in the impregnation of steel with zinc and aluminum, and their use commercially is decreasing. Hot dipped galvanizing and electroplated zinc are replacing the sherardizing treatment because they are cheaper. Aluminum-chromium-silicon steel alloys are favored rather than calorized parts for many high temperature services, especially in steel tubes.



The silicon impregnation process has been developed within the last six years and has been used commercially in America for about three years, and a plant has recently been started in Sweden. Amorphous silicon carbide as the source of silicon makes it the most economical impregnation method for corrosion protection. Briefly, it consists in placing the part to be treated in a rotary furnace of the carburizing type, in contact with fine amorphous silicon carbide. When the parts and carbide reach a temperature of about 1800° F., a small amount of chlorine is introduced and the reaction continued for one half to three hours depending on the thickness of the case desired. The resulting case is from 0.010 to 0.050 in. thick and contains approximately 14% silicon. It differs from other cases by having an almost uniform silicon content practically down to the interface.

High silicon alloys in the cast form are quite brittle and have poor physical properties. But, in the impregnated article the excellent properties of the common steel core are maintained, while the silicon alloy protects the underlying base metal from corrosive attack. The case is firmly attached to the core and will not crack or spall off by hammering except on sharp corners.

On a production scale, parts may be treated for about the same costs as carburizing similar parts. The size of articles that can be treated is limited only by the furnace capacity. Rotary carburizing furnaces with only minor changes have been found satisfactory for silicon impregnation.

Thousands of automotive parts have been treated and are in commercial use, giving entire satisfaction. Many of these replaced expensive alloy parts or more costly impregnated parts. New uses are being discovered daily.

Cases on high sulphur, high carbon, and alloy steels are not so satisfactory as those on low carbon steel with a sulphur content below 0.04%. Gray cast irons, because of their high sulphur content and tendency to swell at treating temperatures, also offer difficulties in the production of cases as resistant as those on steel.

Of all the ennobling elements usable for impregnation, silicon is the cheapest and most efficient. It has strategic importance in replacing imported chromium and nickel with an element obtained from common silica sand. The time required at temperature is also less than that of other impregnations. Simple, standard equipment can be used. No expensive reducing atmospheres are necessary. Careful technical control of the impregnation process and its applications is essential to obtain maximum results.

It is certain that in the future the fight against the corrosion of metals will continue. Better and less expensive alloys will be developed. Impregnation of cheap base metals with silicon and other ennobling elements should play a large part in this effort to solve the universal problem of metallurgy.

Improved Mechanical Finishes

By Joseph Geschelin
Detroit Technical Editor
Automotive Industries

BRILLIANT work by chemists and metallurgists in cooperation with production people has brought about an entirely new era in the processing of bearings and other types of highly stressed mechanical parts. The past two years have been notable for the advances made in the development of various types of surface treatments, intended to supplement the role of heat treatment.

Among the surface treatments to which we shall refer are "superfinish" and various other mechanical processes designed to eliminate surface imperfections and thus approach ideal bearing and mating surfaces; shot-blasting, for producing mechanically clean surfaces on highly stressed parts and greatly increasing the endurance limit; metallic and chemical coatings for corrosion resistance and self-lubricating properties, tending to greatly reduce wear and eliminate scuffing; and finally, hard electroplated coatings.

One of the most striking of the mechanical developments of the past year was the introduction by Chrysler Corp., of a new production technique called superfinish which removes surface defects produced by any prior method of metal finishing, and reducing surface indentations or scratches due to tool marks to a degree of fineness measured in millionths of an inch. The process is adaptable to parts of any form — flat, round, concave or convex, on internal or external surfaces.

According to the findings of Chrysler Corp., superfinished bearings can move with respect to mating surfaces with a very thin film of lubricant, and with hitherto unknown fineness of clearance. It is a characteristic of the process that all projections are completely removed, leaving only the indentations or valleys, thereby assuring complete lubrication since there are no *points* at which the film may be ruptured. The process is applied with equal success on non-lubricated surfaces such as the brake drum. Here the absence of peaks prevents the tearing of the brake linings, increases service life, and tends to eliminate squeaky action.

Of equal importance is the fact that the process has encouraged further work on fine finishes in other directions and already has resulted in the availability of production machines which may be applied to similar problems by any manufacturer. Too, it has placed great emphasis upon the utility of the profilometer in regular production, a device for measuring tiniest surface imperfections.

In the category of fine surface finishes designed to promote better mating of parts and improve lubrication are a number of other well-known techniques. Most important of these is the development of the current types of honing machines for finishing cylinder bores, connecting rod big ends, wrist pin bores, and other types of bores where it is essential to have not only good surface finish but perfection of dimensional accuracy as well.

For small bores we may note the increasing use of simple mechanical devices such as the use of steel balls or rollers. For example, accurate sizing and fine burnished finish are produced in the valve guide bores of Chrysler six-cylinder engines, and tool posts of Danly die sets, by pressing through the opening a steel ball of exact size.

Other engine builders supplying the automobile industry use the Cogsdill "bearing-ize" machine which sizes and burnishes small bores by rapid peening or hammering action.

One of the most remarkable, albeit simple techniques, which is not too widely known, is the use of shot-blasting for greatly increasing the endurance limit of highly stressed parts. Here the entire surface or portion of the surface is subjected to a heavy bombardment of

fine steel balls which not only removes scratches, notches and other surface imperfections that have an influence upon fatigue failure but produce a compressed surface more capable of resisting fatigue arising from repeated reversals of tensile stress.

Widest production use of this technique was in the manufacturing of the Belleville type clutch disc developed for Chevrolet two years ago. The entire surface of the spring disk is shot-blasted, resulting in a service life far exceeding the most optimistic estimates of the designers.

Shot-blasting also is employed in the finishing of knee-action coil springs, either eliminating the fine ground surfaces hitherto provided, or reducing the amount of machined finish formerly considered desirable.

Another striking use of shot-blasting is found in the machining of rear axle shafts. One manufacturer found that there was an unusual amount of replacement on one of the older models. It was not feasible to increase the critical diameter of the shaft, but shot-blasting at the region of maximum torsional stress was found to eliminate further breakage even more effectively. Another producer has employed shot-blasting in the same manner on axle shafts intended for heavy duty of a regular production vehicle, such as its use for an ambulance chassis.

Metallic and chemical coatings have been employed with signal success in promoting corrosion resistance and in providing surfaces which are self-lubricating and hence eliminate danger of scuffling during the initial break-in period (and at times of deficient lubrication). In motor cars, such coatings are found on piston rings, on camshaft cams, on tappets, and many other places where scuffing and even momentary seizure at starting and during initial break-in have contributed to untimely wear. Many of the proprietary coatings are of chemical nature, such as manganese phosphate, and the sulphidizing process, and at least one is an oxidizing treatment. In many surface treatments, whether metallic or chemical, self-lubricating properties are given by immersing in some form of soluble oil or by treating with colloidal graphite.

In the same category we may include the commonly known treatments such as the anodizing of aluminum alloy pistons, tin plating and cadmium plating of aluminum and cast iron pistons.

Finally it is important to note briefly the role of electroplated coatings of the so-called "hard" or "mechanical" type as distinguished from the coatings intended purely for decorative purposes. In recent years much work has been done with the newly developed heavy bright nickel baths and thick coatings of chromium plate for mechanical purposes.

Hard chromium plating has been variously employed to increase the life of parts such as outboard motor cylinders, pistons, and rings, and has been tried experimentally for coating large engine cylinders and crankshaft journals. Both chromium and nickel, and combinations of these, have been employed for salvage and repair operations — for building up the surfaces of worn bearings or of parts spoiled in production. In such instances the operation is economically justified wherever the initial cost of the part is quite high in comparison with the cost of the salvage operation. Chromium plating has been used in places where self-lubricating and non-seizing properties are desired.

Much work is being carried on along these lines and future developments will merit the close attention of metallurgists. In particular, it is well to note the possibilities of "hard" plating as a means of increasing the life of cutting tools of certain types, and certainly as a means of salvaging expensive forming tools, reamers and gages.

Dry Pickling

By E. G. deCoriolis
Research Director, Surface Combustion Corp.
Toledo, Ohio

ANOTHER OLD ART is in process of being revolutionized. When metal has been heated and oxidized, the heretofore accepted method of cleaning its surface was by immersion in a pickle bath. This method was objectionable, for many obvious reasons, and has only been tolerated because no adequate substitute was readily available. The only known way of avoiding it was to prevent the metal from oxidizing during heat treatment.

Recently there has been developed a new method of removing oxide from a steel surface by attacking the iron oxide with a hot gas. The most adaptable gas for this purpose is hydrogen chloride, for the reason that the ferric chloride formed at the temperature of reaction is a vapor and the conversion of solid iron oxide

into a gaseous salt leaves the surface of the steel chemically clean. This process, which has been designated "dry pickling", is now past the laboratory stage and is being developed under semi-commercial plant operation. Many other uses immediately suggest themselves.

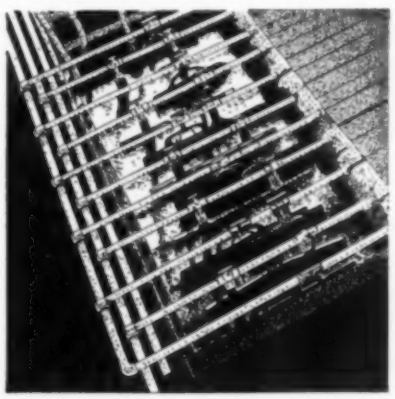
Electroplating and Finishing

By Adolph Bregman
Consulting Metallurgical Engineer
New York City

ELECTROPLATING and metal finishing have had an interesting year. The industry has witnessed the development of several new methods and processes, the appearance on the market of a variety of improved equipment and supplies, and also definite progress in the understanding of some fundamentals.

Methods of depositing hard, heavy nickel plate for industrial purposes (repair, salvage and building-up) were made public by W. A. Wesley. The Travers process for electroplating on aluminum was placed in commercial operation in a number of plants; this process rests on the development of an anodic oxide film, in contrast to the previous methods which consisted of removing all oxides to obtain a bare metal surface. A hot, high-speed copper plating process was perfected by the Du Pont company, which produces bright deposits of heavy thicknesses. A new solution for producing a "white brass" plate (copper-zinc) was described by F. F. Oplinger. The electro-deposition of decorative black molybdenum finishes on zinc base alloys and cadmium surfaces was described by R. A. Hoffman and R. O. Hull.

Steady progress was noted in a number of improvements and refinements in commercial operating methods. Wider use is being made of organic wetting agents to control pitting in nickel solutions. Bright nickel plating is growing consistently. The use of highly finished cold rolled steel for plating is gaining steadily because of the savings in subsequent polishing and buffing to prepare the metal for plating. Electrolytic cleaning of strip steel in caustic solutions is an important aid in this type of work.



Considerable interest is being shown in silver plate for industrial processes. The work of the American Silver Producers Research Project has centered attention on the possibility of using electro-deposited silver in light weights, but substantially pore-free, for food containers and for contact with chemicals.

The manufacture of tin plate by electrolysis has not yet arrived but seems to be coming appreciably nearer. Commercial production by this method should be an accomplished fact at no far distant date.

New equipment and supplies found a fertile field in electroplating. Copper oxide, plate type rectifiers are going into operation, some of the earliest installations having been made in electrotyping plants. A new plating conveyor has appeared, the elevator type, full automatic machine, which is said to have great flexibility, need low head-room, and be suitable for a variety of operations such as plating, coloring, cleaning and pickling.

A new type of nickel anode is in use, a rolled nickel containing 0.25% carbon, for low pH, high speed baths.

Coating of electroplating racks with organic materials for protection and preventing deposition outside of the work itself is making rapid strides toward general use. Anode bags made of glass cloth constitute another interesting improvement.

Continued growth was noticeable in the use of rubber for plating tank linings, the increased use of filtration and filter powders for plating solutions, the wider practice of agitation and also more careful control of the temperature of plating solutions. To a considerable extent this improvement has been due to the use of bright nickel solutions which demand extreme care and close control in their operation.

The fundamentals of electroplating were not neglected. Research has been carried on at the National Bureau of Standards under the auspices of the American Electro-Platers' Society, on the development of specifications for electroplates on non-ferrous metals. There is some question about the continuation of this work, but it is hoped that the research will be carried on to completion.

An important fundamental contribution was made by

Hothersall and Hammond in their work on the porosity of electroplated coatings on steel. They found that porosity can be traced to finely divided solid matter in suspension in the solution, foreign matter on the surface of the steel, and a rough condition of the surface. Successful extension of this work into practical operations should lead to vast improvement in electroplated coatings, suiting them for protective work under conditions which now seem too difficult to cope with.

Extension of plating into industrial fields is leading to a new conception of the use for metallic coatings. Such coatings are suitable not only for decorative work, which has been long known, not only for protective work under proper conditions and with sufficiently heavy coatings, but also to improve the functioning of the product plated, thus adding to its intrinsic value.

No review of electroplating for the past year would be complete without mention of the new edition of the book "Protective Coatings for Metals" by Burns and Schuh. This book, almost completely re-written, is the most important recent addition to the literature, bringing up to date its contents on electroplating, hot dipping, rust proofing, cementation and metal spraying, and adding chapters on lacquering, painting and porcelain enameling.

In the field of non-metallic finishes, lacquer, lacquer enamels and synthetics, changes are still rapid, due to the continual development of new types of synthetics, including such bases as urea-formaldehyde, phenol-formaldehyde, glycerol-pthalic anhydride, and vinyl chloride.

An interesting improvement in lacquering is the use of hot lacquers at 150 to 160° F. The advantages are a lower viscosity of liquid, higher solids content producing thicker films, and a reduction in finishing time. These films are said to be comparable to built-up films of synthetic enamels, but at the same time are fast drying, easily sanded and patched and have high brilliance and clarity of color.

Equipment for applying finishes is being steadily improved in design and by the use of the principles of high production, automatic, straight line systems. Spray guns, spray booths, helmets and respirators are undergoing constant refinement. Baking ovens are now generally under full temperature and heat distribution control.

An interesting improvement in baking methods is the use of gold plated lamps for electrical heating by radiation which is said to effect extraordinary reductions in baking time.

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Jrl Ad T-621(24)

non-ferrous
Heat Treatment

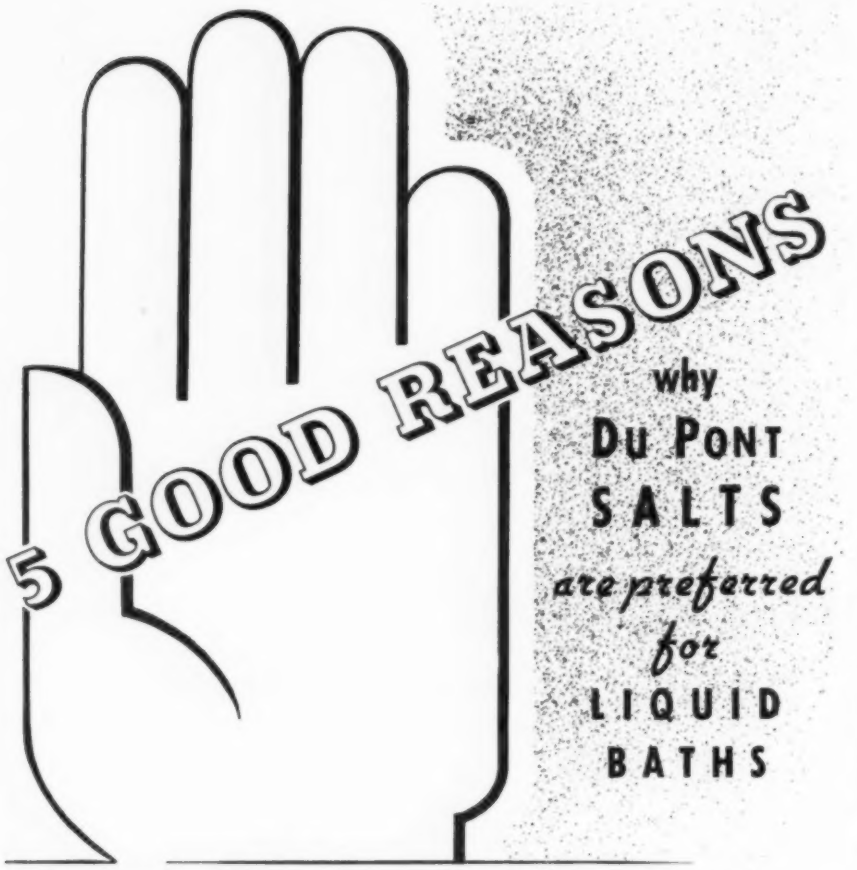
(Continued from Page 377)

in the use of these and newer alloys, difficult to process, there is an increasingly greater need for controlled atmosphere annealing. It is possible now to get standard gas generating units that will generate almost any desired atmosphere from one that is only a slightly reducing carbonaceous atmosphere to one that is highly reducing, sulphur free, moisture free, and even carbon dioxide free. The use of controlled atmospheres will undoubtedly be extended, particularly to those alloys that form oxides difficult to remove by ordinary pickling practices.

Age hardening copper base alloys need a treatment entirely different from regular annealing of standard alloys. They require closely controlled heating at rather high temperatures, rapid quenching, and subsequent prolonged heat treatment at lower temperatures. The steady development and increased application of these special alloys will result in new designs of special production furnaces for this treatment.

Some of the newer sheet mills, recently put into operation, have indicated the trend of the future to much heavier bars of standard wide width in the early stages of brass sheet manufacture. The straight line production layout of this type of mill utilizes heavy automatic production and handling equipment, and the annealing furnaces must conform to this scheme, especially in heating the heavy cakes and annealing the run-down bars. This calls for large capacity furnaces capable of handling very heavy uniform coils or bars, and opens possibilities for continuous furnaces of entirely new design.

Continuous strand or strip annealing of sheet and wire has taken a definite place in brass mill annealing practice. It is now quite a standard practice in wire manufacture, and by the use of controlled atmospheres almost any alloy in wire form can be bright annealed. Considerable work has been done on continuous wire annealing in open flame, and this offers good possibilities for the future. Continuous strip annealing of non-ferrous sheet has not kept pace with wire annealing. It is possible by special controlled atmospheres and continuous strip annealing to bright anneal any non-ferrous alloy sheet. Equipment cost and operating cost handicap the process, but on special alloys it has a definite place.



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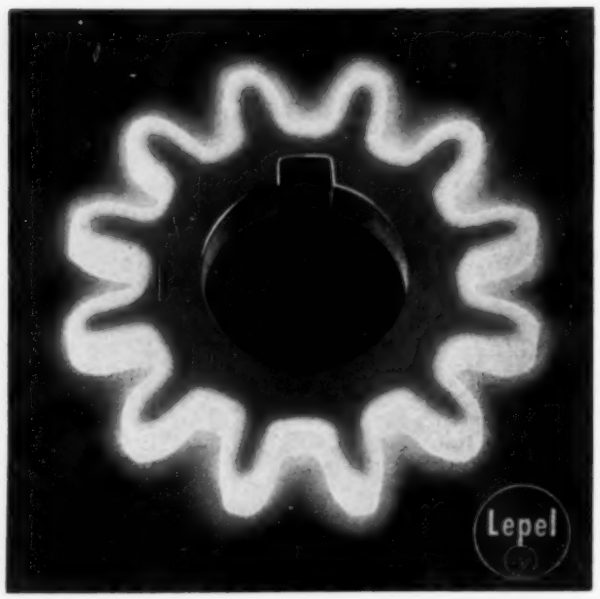

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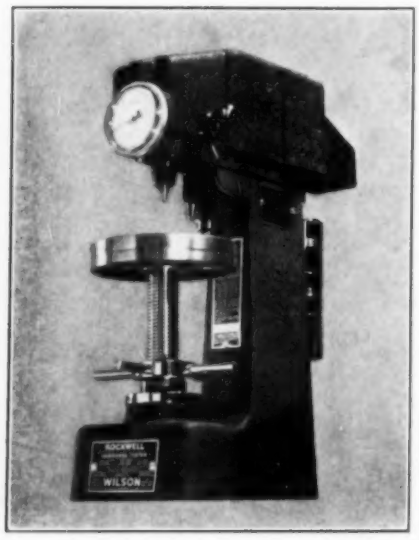

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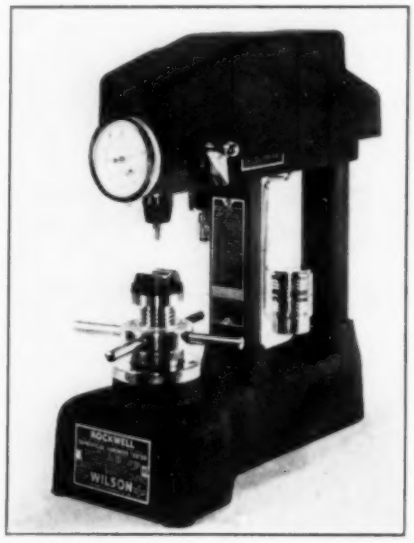

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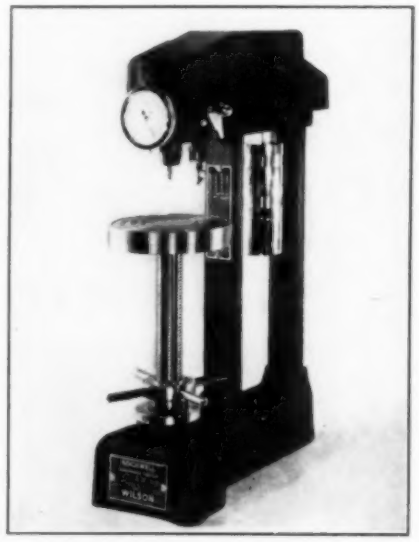

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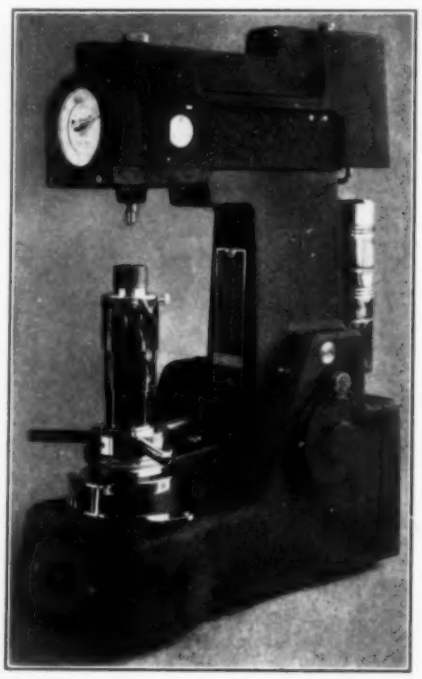

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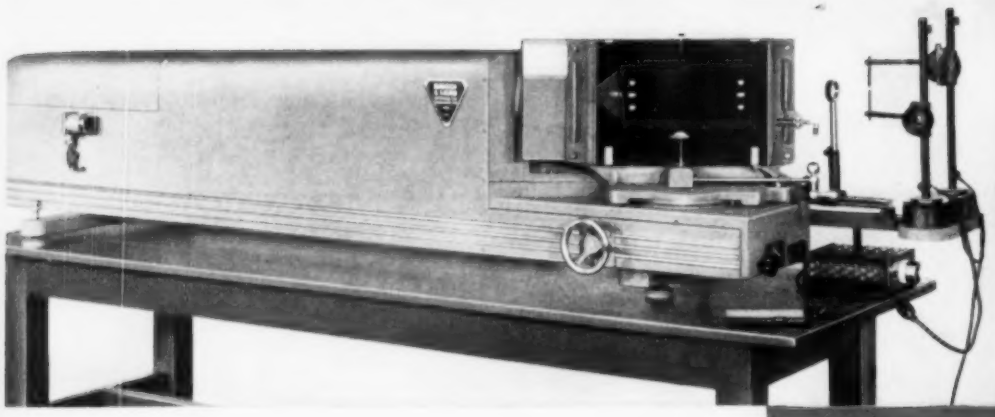

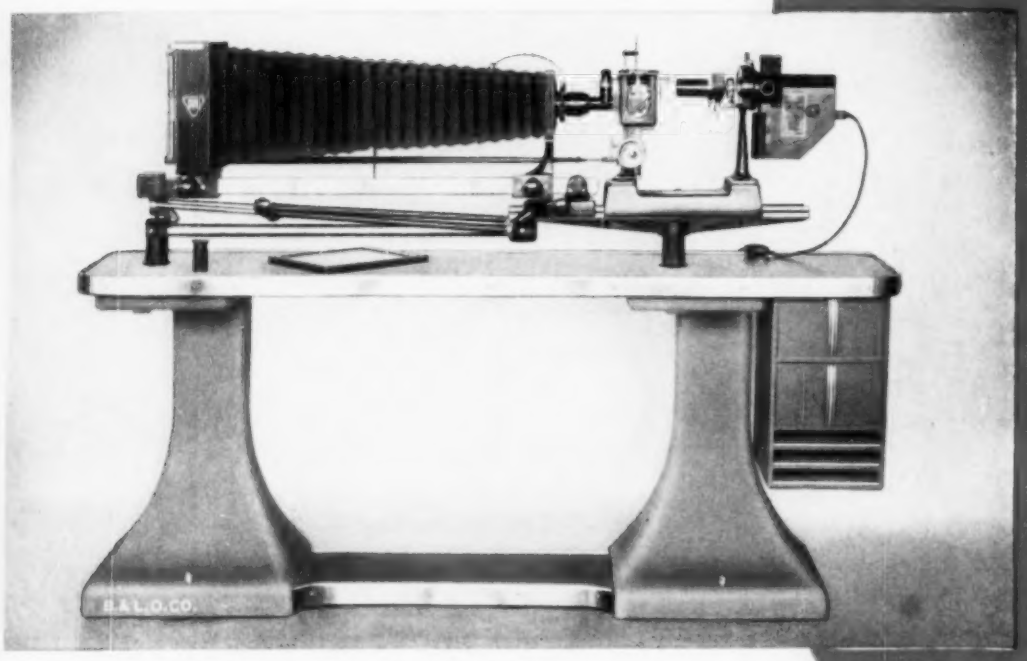

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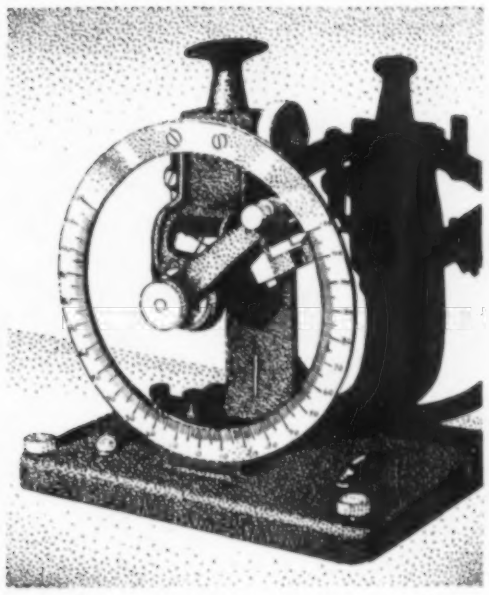

The Instrument Industry

By The Editor

THOSE OF US who remember back to World War No. 1 have frequently been impressed with the growth of instrumentation which that disaster engendered. During 1916 to 1918 innumerable plants manufactured for the first time to close specification. To improve uniformity and to supplement (and even replace) human skill, it was necessary to rely on automatic instruments, first to measure and record, and then to control all manner of processes.

The trends so started have not yet stopped. Rather they have been intensified, since it has become abundantly clear that the product of automatic control is not only better but cheaper. Merely to prove the point the comparative records may be cited of two batteries of similar openhearth furnaces in one tonnage plant; the battery under hand control produced 7.9 tons of steel per furnace-hour and used 6,350,000 B.t.u. of heat per ton; the battery under instrumental control made 8.9 tons and used 5,325,000 B.t.u. per ton.

It is not surprising to find, therefore, that the American industrial instrument industry is deservedly prospering. This we have known in qualitative terms, but never have known just *how* prosperous until seeing a recent study (a WPA national research project of the "white collar" type) entitled "Industrial Instruments and Changing Technology".

Figures on the growth of the industry have been carefully segregated from the U.S. Census and checked by manufacturers' records. Including nothing but instruments for measurement and control of pressure, temperature, flow, and analysis of materials *in direct production* (exclusive of electrical instruments) the figures show that their value was $12,500,000 in 1914, but jumped nearly four-fold during the War and reached $81,000,000 in 1927. By 1936 the recovery had given back $66,000,000 worth of business.

Likewise the rate of growth is really phenomenal. Taking 1929 as 100 in both industries, industrial instrument sales in 1921 measured 22 and of industrial machinery 47; in 1935 instruments stood at 59 and machinery 44. In other words, recovery had been better since 1932, and expansion in the 1921-1935 period about three times as great as for industrial machinery.

Optical Pyrometers

By Mary Baeyertz
Research Metallurgist
Carnegie-Illinois Steel Corp.
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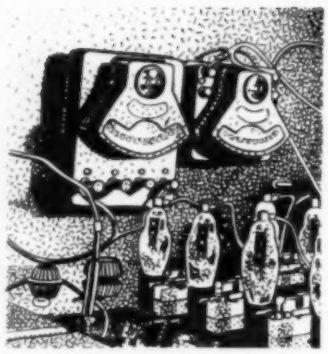
LOOKING TOWARD THE FUTURE of the optical pyrometer, progress may be expected in several fields. One of these is in the temperature scale and its transference to reference and working standards. This work will be done primarily by the few laboratories that are specially equipped to carry out such studies.

The future may also hold a new instrument, which will be as truly an "optical" pyrometer

as the disappearing filament type now so commonly used, but will depend on principles other than the photometric measurement with monochromatic light (now used in the disappearing filament type of instrument). A beginning along this line is the "color" pyrometer for high temperature range developed a few years ago in Germany. The measurement of temperature by this instrument depends on the change in the proportions of red and green light, emitted by a radiating body, with variation in its temperature.



Improvement may also be expected in the disappearing filament type of instrument. A new instrument of this type has recently been developed in which the lamp current is measured by a potentiometer circuit rather than by the milliammeter usually used.

The optical pyrometer will probably remain the instrument par excellence for surveying high temperature operations prior to the installation of recording and controlling equipment, and for other applications in which its mobility and the fact that measurements can be made at a distance from the radiating body are desirable features.

Controllers

By L. G. Bean
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Waterbury, Conn.

WHEN INSTRUMENTS were first used in industry, their original function was to measure; next it was to record. It was then their responsibility to indicate what was going on in the present and to record what had taken place in the past. But today an instrument is often required not only to measure, but also to control — that is, to hold the quantity or condition under measurement within certain fixed limits and in this way to determine what will occur in the future.

Almost all conditions can be controlled. Temperature, pressure, flow, load, mixture — all are today being effectively controlled in widely varying applications. But in the majority of instances, and excepting those of the so-called self-operated type, the use of an auxiliary medium is required. The medium may be air. Or it may be electricity. Either makes possible almost identical results. The deciding factor as to which one or the other is to be used is the plant itself in which the control installation is to be made.

The following paragraphs classify the more common types of control:

I. Electric control, in which electrical energy, supplied from the primary measuring means, operates the secondary means, such as a valve.

I-a. Off-and-On, wherein the valve closes when the reading is high, and opens when the reading is low. It operates with very small change in reading. Off-and-on control is the most important and common fixed-position type, the valve having two positions, either open or closed. It is adaptable to most of the batch processes.

I-b. Three Position Control is a modification of off-and-on which also includes "off", "low" and "high" positions. It is similar to the two-position control, except that it has more than the minimum possible dead space.

I-c. Floating Control, wherein the valve moves slowly towards its closed position when the reading is high, or slowly towards the open position when the reading is low. The valve takes that particular position which will satisfy the load, as long as the process lag is not too great. Floating control may be adjusted, at some sacrifice of rangeability and speed of response, to avoid the violent changes in demand of an off-and-on control.

I-d. Proportioning Control. The valve has a definite throttling range, open full at one end and closed at the other; the valve takes a position in proportion to the demand. It is adapted to continuous work. However, as the load varies, the control point will wander over the throttling range.

I-e. Proportioning with Manual Reset is same as proportioning control, but has a manual means to reset the control point for each load condition.

I-f. Proportioning with Automatic Reset is the same as proportioning control, but has an automatic device in the controller or valve itself to reset the control point for each load condition. It is particularly necessary on continuous processes where wide band (say, more than 15% throttling range) is employed.

II. Air Control, in which compressed air, supplied from the primary measuring means, operates the secondary means, such as a valve.

II-a. Off-and-On. In this type of equipment valve motion is rapid and the range for the adjacent control points is small, probably less than 1% of scale width. Such off-and-on control is adaptable to most of the batch processes. It is the most

important common type of air control, the valve operating relatively rapidly from one position to the other, with a throttling range of less than 1%.

II-b. Proportional Narrow Band; Fixed Sensitivity is a throttling type of control with a narrow throttling range, say, 10%. Provided the process lag is not too great, it does allow the valve to assume a throttling position more than the off-and-on. But since its throttling band is narrow, no appreciable drift in control point with change in load (departure) will take place.

II-c. Proportional Narrow Band; Variable Sensitivity is the same as above, except that means are available to vary the throttling range, generally to not over 20%. It is adapted to processes where the change in load is slight, but where some throttling range or sensitivity adjustment is necessary to prevent hunting.

II-d. Proportional Wide Band, a type of control which has a throttling range from 10% up. As a general thing, if the throttling range is wide, the control is subject to drift in control point with change in load (departure). It is therefore adaptable only to continuous processes, and not often recommended.

II-e. Proportional Wide Band Control with Reset is the same as above, except that it has an automatic means to reset the control point so it will not drift with change in load (departure). Actually, the throttling range is normally very narrow, but is automatically and temporarily widened in proportion to the rate of change, and subsequently restored to its normal narrow value. Most proportional wide band controllers should be equipped with a reset. Such instruments can be furnished with throttling ranges which automatically widen up to 150%.

In connection with the various control instruments described above, throttling range has been considered as that percentage of the instrument scale range which causes the valve in throttling control to go from tight closed to full open. It is the reverse of sensitivity; in other words, a high sensitivity instrument is one of low throttling range and vice versa.

Almost all electric and air controllers, whatever their trade names may be, come into one or the other of the above classes. It can be seen that they meet a wide variety of operating conditions. Proper engineering of an application by a control engineer will determine which type is best adapted to any given process.

High Speed Recorders and Controllers

By C. O. Fairchild
Director of Research, C. J. Tagliabue Mfg. Co.
Brooklyn, N. Y.

DEVELOPMENTS may proceed rather rapidly in the field of temperature measurements in the process industries, toward faster, more accurate recording of temperatures with instruments of simplified design. The more complicated instruments are becoming unacceptable to the men who have to make them go. Faster recording will be in greater demand not only to take care of more temperatures on a single chart as in multiple point recording, but also to record accurately a rapidly changing single temperature.

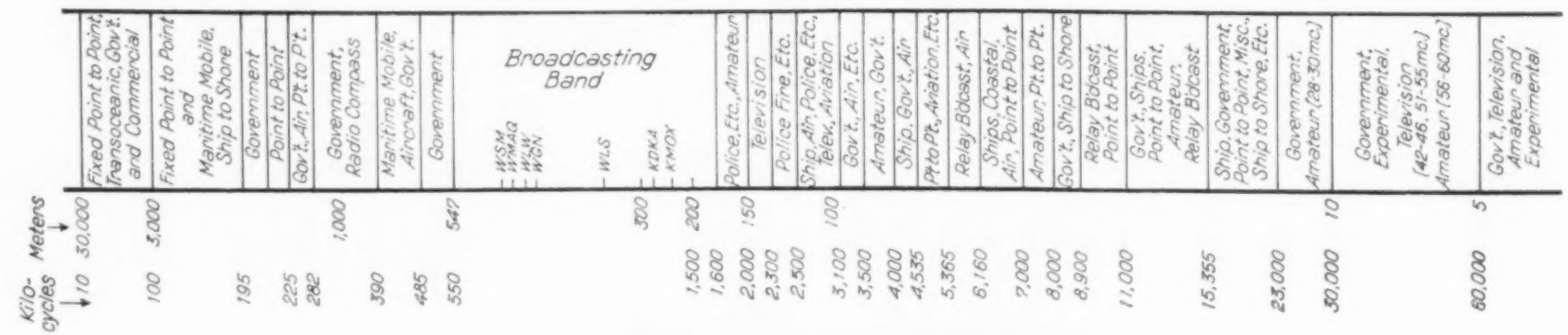
Greater accuracy is to be demanded of the recording electrical thermometers, and thermocouples will therefore be used in preference to resistance thermometers in greater ratio. "Laboratory accuracy" is being approached in many industrial applications.

In the field of automatic control the demand will be marked for simplification of the industrial instruments designed to meet the fundamental requirements with a minimum of "doo-dads". Thinking along these lines leads one to the present fad of coordination of control, that is, the interlocking of various controllers in a single plant unit. To some extent I believe this will be found to be a passing fancy, and further knowledge of the principles of coordination will develop.

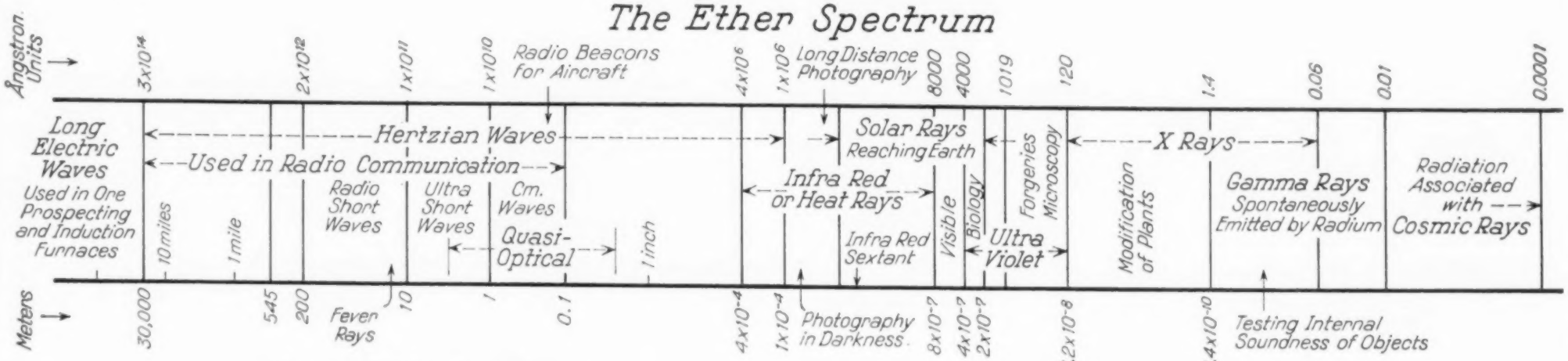
Of all the variables to be measured and controlled in industrial processes, *temperature* plays the primary role of interest. This is borne out by the successful preparations for the temperature symposium to be held by the American Institute of Physics, Nov. 2 to 4 in New York City, to cover "Temperature, Its Measurement and Control in Science and Industry" — and this long title is not too much for the hundred or more scientific and technical papers to be presented.

A special interest to readers of METAL PROGRESS is that R. B. Sosman, the well-known phys-

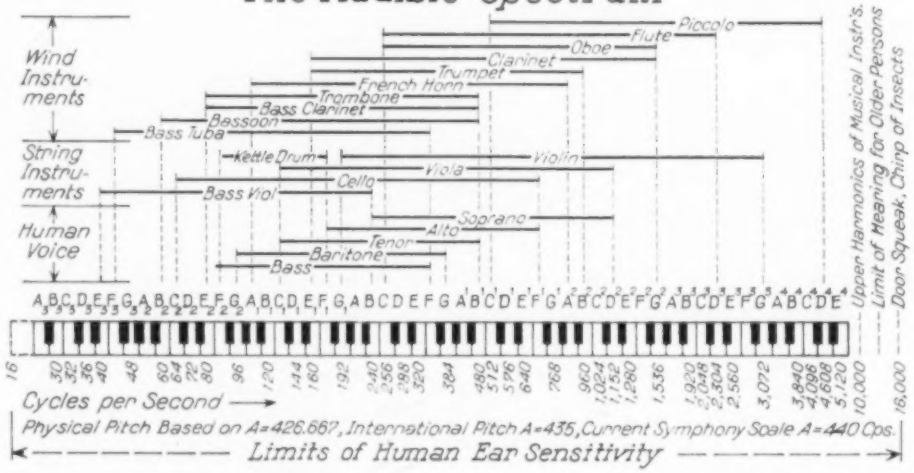
The Radio Spectrum



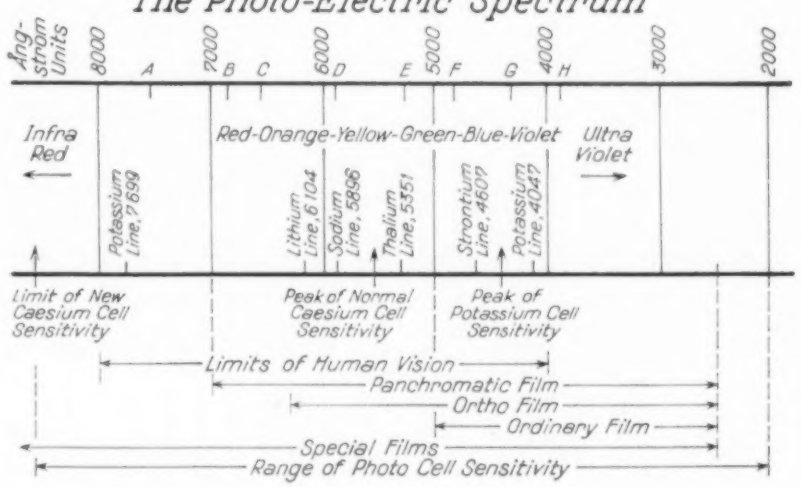
The Ether Spectrum



The Audible Spectrum


Wind Instruments
String Instruments
Human Voice
Piccolo
Flute
Oboe
Clarinet
Trumpet
French Horn
Trombone
Bass Clarinet
Bassoon
Bass Tuba
Kettle Drum
Violin
Viola
Cello
Bass Viol
Soprano
Alto
Tenor
Baritone
Bass
A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E
16 30 32 36 40 48 60 64 72 80 96 120 144 160 192 240 256 288 320 384 480 512 576 640 768 960 1,024 1,152 1,280 1,536 1,920 2,048 2,304 2,560 3,072 3,840 4,096 4,608 5,120 10,000 16,000
Upper Harmonics of Musical Instrs.
Limit of Hearing for Older Persons
Door Squeak, Chirp of Insects
Cycles per Second
Physical Pitch Based on A=426.667, International Pitch A=435, Current Symphony Scale A=440 Cps.
Limits of Human Ear Sensitivity

The Photo-Electric Spectrum



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ical chemist of the U. S. Steel Corp. Research Laboratory, is chairman of the Metals Industries Committee of this symposium, and some very important contributions will be available to metallurgists, revealing present trends of thought and development, and to some extent foreshadowing the way of future progress.

Radiation Pyrometers

By P. H. Dike
Assistant Director of Research
Leeds & Northrup Co., Philadelphia

IN THE PAST YEAR there has been a continued increase in the application of improved radiation pyrometer detectors (now widely known under the trade name Rayotube) to problems in the measurement and control of temperatures. Particularly in the metal industries, both ferrous and non-ferrous, technical workers, when confronted with a difficult problem in temperature measurement, are beginning to inquire first as to the possibility of using one of these devices to secure the desired result.

Radiation pyrometry is solving many temperature measuring problems. For example, it is being applied to:

Forge furnace temperatures, where thermocouple life is short due to breakage.

High temperatures, as in cement and porcelain kilns, where heavily lagged platinum thermocouples are slow in response.

Low temperatures, much below incandescence, as in rail annealing, or mold temperatures just before pouring.

Temperatures of furnaces containing contaminating gases, where the Rayotube is a true thermocouple substitute, it and a closed-end tube forming a complete detecting unit. The closed-end tube projects into the furnace, with the air-cooled or water-cooled sensitive element attached to its outer end.

Surface temperature of billets, rods or rails in the open, to determine variations in temperature as the work progresses.

Surface temperature of the work in heating furnaces of the continuous type with mechanical arrangements to avoid errors due to flame, smoke and reflection. This is of particular value in furnaces where, for the sake of economy in floor space, and to save furnace costs, a high heat head is used. The furnace temperature may be 200 to 300° F. higher than that of the work at discharge, and the furnace operation should be controlled from the work temperature rather than from the furnace temperature, in order to meet variations in mill activity. The method is applicable to small continuous heat treating furnaces, to medium sized billet heating furnaces, both ferrous and non-ferrous, and to the large preheating furnaces in steel mills.

Much remains to be done in the applications mentioned as well as in other fields, such as the very important and difficult one of molten metal temperatures. The radiation pyrometer promises the successful measurement of the temperature of steel in the openhearth furnace before tapping, and is being used to record and control the temperature in a casting furnace in a brass foundry, as well as iron and slag temperatures from blast furnaces.

In this type of pyrometer the sensitive element leads a protected life, shut away from injurious atmospheres and in surroundings at a comfortable temperature, looking out through a quartz window at the hot surfaces in which it is interested and warmed by them to a mild and comfortable degree. If its window is kept clean, it may look into a furnace at 3000° F. for months on end without the slightest deterioration, and measure its temperature as accurately as when first installed. A thermocouple, on the contrary, must enter the furnace, and touch the body in which it is interested to find out what its temperature is; it is thus exposed to contaminating gases and high temperatures, and its life may be strenuous and short.

Hardness Testing

By Howard Scott
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Westinghouse Research Laboratories
East Pittsburgh, Pa.

IN ORDER TO AVOID the highly controversial aspects of this subject, hardness is used here only in the narrow sense of resistance to static penetration. When "hardness" is said, the metallurgist visualizes a static penetration test. The most widely used hardness tests fall in this category. Their principles of action are well understood, but there are many problems in their application and interpretation of results which deserve attention.

One arises from the fact that certain hardness testing instruments use impression diam-

eter while another group uses impression depth as a measure of hardness. Is the same property measured by both types of test?

A recent study of the relations between a representative test of each type has shown that the elastic modulus of the metal tested is an important factor in the relation. (A paper on this subject will be presented at the forthcoming Metal Congress.) For example, at 900 on the diamond pyramid hardness scale (d.p.h.) the Rockwell hardness of steel is 67.5 on the C scale, while that of a sintered carbide having about 2½ times the elastic modulus of steel is 65.5.

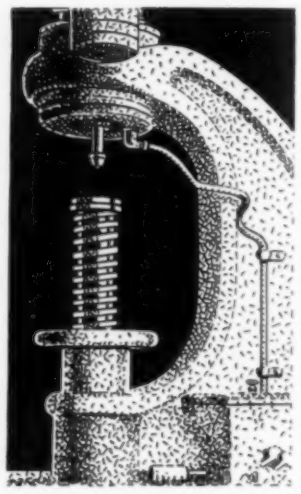
This fact is surprising, since hardness apparently measures resistance to plastic deformation. Analysis of these tests such as was made in a paper presented last year in TRANSACTIONS (page 363) shows clearly enough, however, why this effect should be found. There is relatively much more elastic spring-back after release of load in the depth measuring test than in the diameter measuring test. As a consequence, with the same load and impression diameter the former test gives a higher hardness number the lower the elastic modulus of the metal tested. This fact may be expressed quantitatively in an empirical equation.

The large number of hardness conversion charts in circulation testify to the need for them, but large discrepancies between individual charts suggest basic objections to their use. One difficulty and cause of inconsistency is, of course, the elastic spring-back just described. Evidently a conversion chart between a depth and a diameter measuring hardness scale can be accurate only for metals having approximately the same elastic modulus. Other causes of error are also known, but when they are eliminated conversion tables can undoubtedly be used with confidence.

Metallurgists are unduly burdened with the necessity of being familiar with a large number of hardness scales. Why will not one reference scale suffice for purposes of record and communication? If accurate conversion is feasible, as the present evidence indicates, we need talk in only one hardness language. Though elastic modulus must be taken into account, so doing is not burdensome because elastic modulus is a structure-insensitive property and, therefore, affected very little by kind or quantity of an alloy content. Practically all metals and alloys fall into four classes on this basis. An endeavor to use a single hardness scale will undoubtedly be made in a small way as soon as complete conversion data are available.

If a single reference hardness scale is used, what scale will serve this purpose best? Certainly a test employing a diamond penetrator is essential to cover the range of hardness found in metals. From a practical viewpoint, an indenter in the shape of a pyramid is preferable to one cone shaped. The universally accepted method of computing hardness numbers as load in kilograms divided by area in millimeters of the impression as loaded should, of course, be continued. The test thus specified (the diamond pyramid hardness test) provides the best reference scale among those in current use.

Equipment for making the diamond pyramid hardness test is developed and available, but one may question that it provides the ultimate reference standard. In fact some work just published by Knoop and others at the National Bureau of Standards suggests that the ideal form of indenter is not a rectangular pyramid but one producing a rhombus shaped impression. Hardness numbers for such an indenter are computed from the length of the long diagonal and elastic spring-back is completely eliminated by choice of a favorable ratio of diagonals, about 7 to 1.



With a diamond indenter of this shape it is possible to determine the hardness of glass and other brittle materials without chipping. In fact the originators of this indenter evaluated Moh's hardness scale in terms of penetration hardness by its use. This form of indenter, therefore, may be the logical successor of the rectangular pyramid. In any event there will undoubtedly be renewed interest and experimental activity in hardness testing during the coming year.

Mechanical Testing of Tomorrow

By R. L. Templin
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PROGNOSTICATION of future vogues in the mechanical testing field is just about as hazardous as trying to guess the future boundaries of European nations. If we confine our prophecies to the relatively near future, however, certain trends can be extrapolated with reasonable expectation of fulfillment.

It seems reasonable to expect a continued interest in the usual static mechanical properties of materials because of our backlog of information on these properties, their uses in product specifications, their value in controlling fabrication processes, and as a basis for selecting engineering design values.

A number of mechanical property test procedures have been developed recently which undoubtedly will be used more extensively in the near future. Among these may be mentioned the new hardness test and the pack compression test for thin sheet metals developed at the National Bureau of Standards.

There is a real need for improvements in much of our present mechanical testing apparatus and much work is being done, by both manufacturers and users, to improve testing machines. Available strain gages, for one example, leave much to be desired in many necessary applications.

Development work is now being actively prosecuted with the object of increasing the accuracy and reliability of our present laboratory tests, and widening their scope. Horace W. Gillett ably pointed out, in his Henry Marion Howe Lecture, what we don't know about creep of metals. In so doing, he has shown the shortcomings of the test methods and apparatus now in use, and indicated the work planned or under way to improve the conditions he has described. Because of the real need for further data on the creep of metals, we may confidently expect not only better methods of testing in this field, but also a broadening of the field now under investigation.

The behavior of materials when stressed beyond their elastic ranges is of considerable importance in the design of some of our modern structures, such as aircraft. The problems presented are beyond the scope of the classical theory of elasticity, and the present theory of plasticity is as yet not a satisfactory tool for their solution. Photo-elastic methods are apparently inadequate, but satisfactory solutions for such problems are being obtained by the use of experimental analysis of actual structures or models, under both laboratory and service conditions. The need for further development of these methods is quite apparent, with the result that an increased activity may be expected in this field of testing.

The designing engineer is becoming more and more concerned with the dynamic properties of the materials in today's structures and machines, and those which will go into the structures of tomorrow. These "streamlined" structures of tomorrow are expected to function more efficiently than those of today, and to do this they must be divested of superfluous material to conserve space, reduce weight, and prevent waste of power in their use. Simultaneously, however, they must be provided with increased stability and strength. Whether materials now known or new ones are used for building these structures, more definite information concerning their behavior under dynamic forces must be available if they are to function satisfactorily. We may, therefore, expect an increasing interest in fatigue, vibration and impact testing. These tests will be amplified so as to place more emphasis on effects of *factors* of design and use, such as stress raisers, stress ranges, combined stresses, corrosion, corrosion inhibitors, temperature, and speed.

Accelerated tests of structural assemblies, such as joints, beams, columns, frames and panels, under both static and dynamic loads, have given results that are more informative and convincing than those obtained by using only the physical properties of the materials involved and the classical methods of design. While such tests often point the way to improvement in design, yet they need to be more closely correlated with service conditions. This in turn will require more definite information on the actual behavior of structures in service.

Efficient design of structures from high strength materials generally results in components having relatively high slenderness ratios. When such structures are required to operate at high speed or under conditions involving vibration, the natural frequencies of the various parts and of the structure as a whole

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio c ÷ a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IA in Periodic Sequence									
3 Lithium	(2)1	⊞	—	8	3.51±0.04	—	3.04	—	3.13
11 Sodium	(2)(8)1	⊞	—	8	4.30±0.04	—	3.72	—	3.83
19 Potassium	(2)(8)(8)1	⊞	—	8	5.3335	—	4.618	—	4.76
37 Rubidium	(2)(8)(18)(8)1	⊞	—	8	5.62±0.03 at -173°C.	—	4.87 at -173°C.	—	5.02
55 Cesium	(2)(8)(18)(18)(8)1	⊞	—	8	6.05±0.03 at -173°C.	—	5.24 at -173°C.	—	5.40
87 Virginium	(2)(8)(18)(32)(18)(8)1	—	—	—	—	—	—	—	
Group IB									
29 Copper	(2)(8)(18)1	⊡	—	12	3.6078	—	2.5511	—	2.551
47 Silver	(2)(8)(18)(18)1	⊡	—	12	4.0778	—	2.8835	—	2.883
79 Gold	(2)(8)(18)(32)(18)1	⊡	—	12	4.0699	—	2.8778	—	2.877
Group IIA in Periodic Sequence									
4 Beryllium	(2)2	⬡	1.5848	6,6	2.2679	3.5942	2.2235	2.2679	2.25
12 Magnesium	(2)(8)2	⬡	1.6236	6,6	3.2022	5.1991	3.1900	3.2022	3.20
20 Calcium	(2)(8)(8)2	α=⊡	—	12	5.56	—	3.93	—	3.93
(data for 450°C.) →		β=⬡	1.640	6,6	3.94	6.46	3.94	3.955	3.98
38 Strontium	(2)(8)(18)(8)2	⊡	—	12	6.075	—	4.296	—	4.296
56 Barium	(2)(8)(18)(18)(8)2	⊞	—	8	5.015	—	4.343	—	4.48
88 Radium	(2)(8)(18)(32)(18)(8)2		—	—	—	—	—	—	—
Group IIB									
30 Zinc	(2)(8)(18)2	⬡	1.8560	6,6	2.6590	4.9351	2.6590	2.9061	2.748
48 Cadmium	(2)(8)(18)(18)2	⬡	1.8852	6,6	2.9736	5.6069	2.9736	3.2872	3.042
80 Mercury	(2)(8)(18)(32)(18)2	▱	α=70°31.7'	6	2.999 ← at -46°C.		2.999	—	3.10
Group IIIA in Periodic Sequence									
5 Boron	(2)3		—	—	—	—	—	—	2.80 to 2.86 (note b)
13 Aluminum	(2)(8)3	⊡	—	12	4.0414	—	2.8568	←	
21 Scandium	(2)(8)(9)2		—	—	—	—	—	—	
39 Yttrium	(2)(8)(18)(9)2	⬡	1.588	6,6	3.663	5.814	3.595	3.663	3.629
57 Lanthanum	(2)(8)(18)(18)(9)2	α=⬡	1.613	6,6	3.754	6.063	3.727	3.754	3.741
		β=⊡		12	5.296		3.754		3.745
89 Actinium	(2)(8)(18)(32)(18)(9)2		—	—	—	—	—	—	—
Group IIIB									
31 Gallium	(2)(8)(18)3	▯	—	—	4.5167	7.6448	(note c)	—	—
		a÷b÷c=1:0.99868:1.69257			b=4.5107				
49 Indium	(2)(8)(18)(18)3	◬	1.077	4,8	4.583	4.936	4 at 3.241	8 at 3.368	3.138
81 Thallium	(2)(8)(18)(32)(18)3	α=⬡	1.600	6,6	3.450	5.520	3.404	3.450	3.427
		β=⊡	—	12	4.841	—	3.423	—	3.423

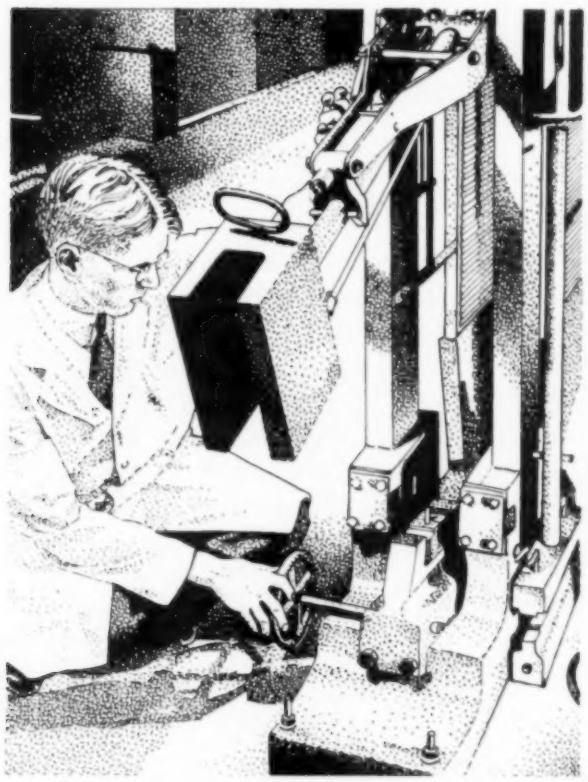
Notes: (a) ⊞ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal; ▱ is simple rhombohedral; ▯ is orthorhombic; ◬ is face-centered tetragonal

(b) Appears to be smaller in some alloys

(c) 8 atoms to unit cell; each atom has 1 neighbor at 2.437, 2 at 2.706, 2 at 2.736 and 2 at 2.795

must be given serious consideration. There is a conspicuous lack of knowledge of the vibration characteristics of most engineering structures. Furthermore, if the vibration characteristics are determined for a given structure and found to be undesirable, the solutions to the problems presented are often unsatisfactory. The increasing number of problems of this type will undoubtedly stimulate new testing work.

Development and use of new materials possessing new combinations of mechanical properties will require a critical review of the significance of the various mechanical properties and their values in structural design, as well as structural behavior under service conditions.



Spectrography in 1939

By Thomas A. Wright
Secretary and Technical Director, Lucius Pitkin, Inc.
New York City

NEW INSTALLATIONS of prism and grating instruments are more and more numerous, with continued indications that the grating type is gaining preference despite the fact that industry is still leaving it to two or three universities to produce the actual gratings. Conversely the prism manufacturer has been dependent chiefly upon the deposits of optical quartz in the mineralogist's paradise in the State of Minas Geraes in Brazil, but as radio and television are using increasing quantities of high grade quartz crystals, added incentive is offered for the discovery and exploitation of new fields so there probably will not be a real scarcity such as some fear. There is still considerable unexplored territory, both as to area and depth, on and in the well-known earth. As to gratings, there is also apparently a field for reasonably priced spectrographs employing replica gratings.

Other than the merits and fields of application of the two general types of spectrograph, interest during the year has, publicly at least, continued to center upon methods of excitation. This was brought out vividly at the symposium conducted by Committee E-2 at the June meeting of the American Society for Testing Materials. Next in importance (as also evidenced by spirited discussion) were methods of measuring the "graying" of the lines. Photometric apparatus is tending even more to supplant visual measurement, and the projection comparator is growing in favor. The next five years — judged by the last five — will show much greater progress along these lines. A number of individual workers are designing or are using their own micro-densitometers, and the firm of Leeds and Northrup has also placed a line of equipment on the market.

Except for some noted instances, sampling and sample preparation seemingly are too blithely ignored or glossed over when, as a matter of fact, due to the small amount of material employed in excitation or the small increment of the desired element, most of the costs and responsibility may often come under that head. For example, some of the discussions on the merits of arc vs. spark at the formal and bull sessions at the A.S.T.M. symposium and the subsequent one at Massachusetts Institute of Technology seemed beside the point. It should be obvious that three criteria govern: One, the sample should be representative; two, in such a form that it properly responds to the method of excitation; three, of correct weight. Excitation current and exposure time should be so adjusted that neither too little nor too much of the desired element is registered. Those workers who must deal with a heterogeneous number of materials may be confused at times as to what is the desired combination of techniques, but some of those who only work on one or two types of base alloys may be fooled by a seeming simplicity.

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No. 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio c ÷ a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IVA in Periodic Sequence									
22 Titanium	[2][8][10]2	⬡	1.601	6,6	2.953	4.729	2.915	2.953	2.93
40 Zirconium	[2][8][18][10]2	α= ⬡	1.589	6,6	3.223	5.123	3.166	3.223	3.19
[data for 867°C.]		β= ⊞	—	8	3.61	—	3.126	—	—
72 Hafnium	[2][8][18][32][10][2]	⬡	1.587	6,6	3.200	5.077	3.139	3.200	3.17
90 Thorium	[2][8][18][32][18][10][2]	⊡	—	12	5.077 or 5.091	—	3.590 or 3.600	—	—
Group IVB, Including Carbon and Silicon									
6 Carbon, diamond	[2]4	◇	—	4	3.5606	—	1.5113	—	—
graphite	—	⬡ (b)	2.75	6	2.46	6.78	1.42	2.46	—
14 Silicon	[2][8]4	◇	—	4	5.418	—	2.346	—	—
32 Germanium	[2][8][18]4	◇	—	4	5.647	—	2.445	—	2.788
50 Tin, gray	[2][8][18][18]4	◇	—	4	6.46	—	2.797	—	3.164
white	—	△	0.5456	4,2	5.8194	3.1753	3.0161	3.1753	—
82 Lead	[2][8][18][32][18]4	⊡	—	12	4.9389	—	3.4923	—	3.494
Group VA in Periodic Sequence									
23 Vanadium	[2][8][11]2	⊞	—	8	3.033	—	2.627	—	2.69
41 Columbium	[2][8][18][12]1	⊞	—	8	3.294 ±0.001	—	2.853	—	2.94
73 Tantalum	[2][8][18][32][11]2	⊞	—	8	3.298 ±0.002	—	2.854	—	2.94
91 Protoactinium	[2][8][18][32][18][11]2		—	—	—	—	—	—	—
Group VB									
7 Nitrogen	[2]5	α=cubic	—	—	5.66	—	1.06	—	—
15 Phosphorus	[2][8]5	▱	α=34° 7′	3,3	5.14	—	1.74	3.01	—
33 Arsenic	[2][8][18]5	▱	α=53°49′	3,3	4.151	—	2.5086	3.1465	—
51 Antimony	[2][8][18][18]5	▱	α=57° 5′	3,3	4.497	—	2.879	3.378	3.228
83 Bismuth	[2][8][18][32][18]5	▱	α=57°16′	3,3	4.7365	—	3.105	3.474	3.64
Group VIA in Periodic Sequence									
24 Chromium	[2][8][13]1	α= ⊞	—	8	2.8786	—	2.4929	—	2.57
		β= ⬡	1.626	6,6	2.717	4.418	2.709	2.717	2.71
42 Molybdenum	[2][8][18][13]1	⊞	—	8	3.1403	—	2.7196	—	2.80
74 Tungsten	[2][8][18][32][12]2	α= ⊞	—	8	3.1583	—	2.7352	—	2.82
		β, (c)	8 atoms in unit cell →		5.038		2.519	2.816	
92 Uranium	[2][8][18][32][18][12]2	Mono-clinic	a÷b÷c=1÷1.73÷1.17 β=64°18′		2.829	3.308 b=4.887	2.829 ← Note d		—
Group VIB									
8 Oxygen	[2]6	—	—	—	—	—	—	—	—
16 Sulphur	[2][8]6	▯ (d)	2.315	—	10.61	24.56	—	—	—
34 Selenium	[2][8][18]6	⬡ (e)	1.140	2,4	4.337	4.945	2.316	3.457	—
52 Tellurium	[2][8][18][18]6	⬡ (e)	1.33	2,4	4.445	5.912	2.858	3.46	—
84 Polonium	[2][8][18][32][18]6	—	—	—	—	—	—	—	—

Notes: (a) ⊞ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal except as noted; ◇ is diamond; △ is tetragonal; ▱ is rhombohedral and ▯ is orthorhombic

(b) Graphite is hexagonal, not close packed, with four atoms per unit cell.

(c) Cubic structure; two positions distinguishable, X and Y. Each atom X has 12 Y at 2.816 Å; each atom Y has 2 Y at 2.519 and 4 X at 2.816 Å

(d) 128 atoms in unit cell. Data from International Critical Tables or A.S.M. Metals Handbook

(e) Hexagonal, not close packed; each atom has 2 neighbors at d_1 and 4 at d_2

Scientifically, the line between arc and spark seems rather shadowy. Practically, the spectrographer depends upon the arc to give him a high temperature and thus a vapor phase, while in the spark the temperature effect is not noticeable and the desired effect is one of electron excitation.

It is a long cry from the 70's to now, but it seems as if the break has come and that from now on we shall hear more of the routine use of the spectrograph in the steel industry, not only in investigating the metal but also the slag and the refractories. How slow and intermittent progress may be is illustrated by mentioning an old book on Spectral Analysis, privately printed, which came into the writer's possession some time ago. John Parry, the author, in discussing the application of the spectroscope to the detection of adventitious elements (including gases, if you please) in iron and steel as affecting the chemical and mechanical properties, emphasized the necessity for recognizing these minute metals, metalloids (compounds too), and gases, and of determining them quantitatively. Parry even studied a plan of controlling, by spectroscopic study, the vapors from "ordinary blast and heating furnaces". He studied in addition gray iron, spiegeleisen, iron ores and ordinary steels. He photographed the spark spectra, employing the prism, and recommended the use of the photograph rather than the eye.

This year photographic technique came more to the fore. There is still room for improvement. It is more important than some think.

An outstanding contribution to spectroscopy was the final publication of the long awaited Wave-Length Tables under the editorship of George R. Harrison of Massachusetts Institute of Technology. These tables, the most comprehensive by far, include some 110,000 spectrum lines in the range 10,000 to 2,000 Å, with intensities in the arc, spark and discharge tube shown by a new and useful system.

The year also saw the publication of a comprehensive textbook on Chemical Spectroscopy by Wallace R. Brode of Ohio State University. Both books should certainly be in the practicing spectroscopist's library.

Metallography

By J. R. Vilella
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Kearny, N. J.

BARRING unforeseen and untoward conditions arising out of the present European war, there is no reason to doubt that the contributions of metallography to steel technology will continue to be as fruitful in practical results as in the past years. All indications at present point to a continued interest in the art and science — and probably further valuable contributions will be made along the same lines as during the last few years.

In the control laboratory of the steel mill the microscope will probably hold its present position as an indispensable tool in the solution of production problems and in the investigation of service failures. In the research laboratory it probably will remain focussed on such fertile fields of investigation as (1) the isothermal transformation of plain carbon and alloy steels, (2) correlation of the structure of steel to such properties as resistance to creep at high temperature and to impact at low temperature, (3) further studies of hardenability and grain size, (4) correlation of the structure and properties of alloy steels, and (5) further studies of precipitation phenomena, such as aging.

It would not be surprising to see a determined effort in the near future to relieve metallography of the burden of a totally unscientific and inadequate nomenclature of steel structures.

It is not difficult to foresee that, in the field of metallographic technique, the present-day efforts to develop improved methods of polishing, etching and photomicrography will continue as heretofore. The introduction of lead laps for polishing has proved to be a valuable improvement and it can be safely predicted that more metallographers will eventually adopt them for the preparation of flat surfaces.

The increased interest in the structure of alloy steels might well be the needed stimulus toward the development of improved etching reagents. While up to the present no outstand-

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No. 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio c ÷ a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group VII A in Periodic Sequence									
25 Manganese	(2)(8)(13)2	α = Cubic (note b)	—	—	8.894	—	—	—	—
		β = Cubic (note c)		12	6.300	—	—	—	—
		γ ⇒ △	0.934	—	3.774	3.526	2.582	2.669	—
43 Masurium	(2)(8)(18)(14)1	—	—	—	—	—	—	—	—
75 Rhenium	(2)(8)(18)(32)(13)2	⬡	1.6148		2.7553	4.4493	2.7349	2.7553	2.75
Group VII B									
9 Fluorine	(2)7	—	—	—	—	—	—	—	—
17 Chlorine	(2)(8)7	—	—	—	—	—	—	—	—
35 Bromine	(2)(8)(18)7	—	—	—	—	—	—	—	—
53 Iodine	(2)(8)(18)(18)7	▯	a÷b÷c = 1÷1.51÷2.04		4.795	9.780 b = 7.255	2.70	(note d)	—
85 Alabamine	(2)(8)(18)(32)(18)7	—	—	—	—	—	—	—	—
Group VIII in Periodic Sequence									
26 Iron	(2)(8)(14)2	α = ⧈	—	—	2.8610	—	2.4777	—	—
		γ = ⊡	—	—	3.64 ← at 900°C.		2.5810	—	2.52
27 Cobalt	(2)(8)(15)2	α = ⬡	1.624	—	2.507	4.072	2.499	2.507	2.50
		β = ⊡	—	—	3.545	—	2.507	—	2.507
28 Nickel	(2)(8)(16)2	α = ⬡	1.64	—	2.49	4.08	2.49	2.49	2.49
		β = ⊡	—	—	3.5170	—	2.4869	—	2.487
44 Ruthenium	(2)(8)(18)(15)1	⬡	1.585	—	2.695	4.273	2.643	2.695	2.67
45 Rhodium	(2)(8)(18)(16)1	⊡	—	—	3.7955	—	2.6838	—	2.684
46 Palladium	(2)(8)(18)(18)-	⊡	—	—	3.8824	—	2.7453	—	2.745
76 Osmium	(2)(8)(18)(32)(14)2	⬡	1.578	—	2.730	4.309	2.669	2.730	2.70
77 Iridium	(2)(8)(18)(32)(15)2	⊡	—	—	3.8312	—	2.7091	—	2.709
78 Platinum	(2)(8)(18)(32)(16)2	⊡	—	—	3.9158	—	2.7689	—	2.769
Rare Earth Group									
58 Cerium	(2)(8)(18)(19)(9)2	α = ⬡	1.62	6,6	3.65	5.91	3.63	3.65	3.64
		β = ⊡	—	12	5.143	—	3.637	—	3.637
59 Praseodymium	(2)(8)(18)(20)(9)2	⬡	1.620	6,6	3.657	5.924	3.638	3.657	3.65
60 Neodymium	(2)(8)(18)(21)(9)2	⬡	1.608	6,6	3.657	5.88	3.619	3.657	3.64
68 Erbium	(2)(8)(18)(29)(9)2	⬡	1.63	6,6	3.74	6.09	3.73	3.74	3.73

Notes: (a) ⧈ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close-packed hexagonal; ▯ is orthorhombic

(b) Approximates ⧈ where each lattice point is a cluster of 29 atoms; 1 type X, 4 type A, 12 type D_2 and 12 type D_1. The X atoms occupy the largest volume and the D_2 the smallest. Interatomic distances of neighboring atoms are as follows:

X atoms have 12 D_2 at 2.71
4 A at 2.82

A atoms have 1 X at 2.82
3 D_1 at 2.49 and 3 at 2.96
3 D_2 at 2.69 and 3 at 2.89

D_2 atoms have 1 X at 2.71
2 A at 2.69 and 1 at 2.89
1 D_2 at 2.24 and 2 at 2.38
1 D_1 at 2.45, 2 at 2.51 and 2 at 2.66

D_1 atoms have 1 A at 2.49 and 1 at 2.96
1 D_2 at 2.45, 2 at 2.51 and 2 at 2.66
6 D_1 at 2.67

(c) Complicated structure with 20 atoms of two kinds in unit cell.

Each atom of the first kind has
3 neighbors at 2.365
3 " " 2.530
3 " " 2.671
3 " " 2.675

Each atom of the second kind has
2 neighbors at 2.530
2 " " 2.615
4 " " 2.659
2 " " 2.671
2 " " 2.675

(d) Atoms arranged in pairs so that each one has one close neighbor at 2.70. Data from A.S.M. Metals Handbook.

ing contributions have been made on the application of polarized light, ultra-violet light and darkfield illumination to metallographic problems, these new tools are potentially fruitful and can be expected to fulfill their promise.

Radiography

By Kent R. Van Horn
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THE PAST YEAR in radiography has contributed some small but beneficial refinements in X-ray apparatus, accessories and technique. No startling advances have as yet appeared above the horizon.

The size of the focal spots of the X-ray tubes that are used for industrial radiography have received attention. The standard 220,000-volt tubes used for the examination of moderate sections of steel have focal spots of about 0.5 in. or 13 mm. in diameter. The focal diameter of the new tubes has been reduced to about 6.5 mm. without any sacrifice in the speed of the equipment. It is now possible to approach the greater detail obtained by the fine focus tubes used for the examination of light alloys. In this fine-focus range of commercial X-ray tubes, decrease in focal areas with the focal distances usually employed slightly increases the definition but the improvement is generally of little commercial significance. The finest focus tube should be selected that will economically penetrate the various sections encountered.

A new and very reasonably priced 140,000-volt tube and apparatus has been recently developed. This apparatus is a completely shock-proof unit, weighs only 45 lb. and can penetrate about 1¼ in. of rolled steel or 5 in. of aluminum. The effective focal spot, 4.5 x 4.5 mm., represents a 50% reduction in area of the former fine focus X-ray tube. The new tube has a 30° target angle rather than the conventional 45° angle, and therefore permits a larger film coverage for a given focal distance.

The applications of radiography continue to expand and the interest of industrial concerns appears to have considerably increased. It is estimated that about 25 new units have been installed in the welding and casting fields in this country during 1939.

There also have been some interesting developments in accessories. It has always been a problem in industrial radiography to satisfactorily examine castings having both thin and thick sections. These difficulties have generally been overcome by introducing special filtering screens with relatively long exposures, immersion of the article to be examined in a solution having a density comparable to the metal, and adding suitable thicknesses of barium clay, lead putty and lead sheet to the thinner sections to compensate for the shorter exposure. Recently C. D. Moriarty of the General Electric Co., Schenectady, N. Y., has obtained very excellent detail in welds containing rather large beads or accumulations on the surface by blocking with copper shot. The shot must be exceedingly fine and spheres about 5 mils in diameter or approximately ten million to the cubic inch are recommended. Shot of steel or non-ferrous alloys may be utilized when material of other X-ray density is desired.

X-ray protection has been given considerable attention in the past by the International Commission on X-Ray and Radium Protection, and the various specifications have appeared in communications from the Bureau of Standards. This organization has continued to investigate the fundamentals of X-ray protection and has submitted recommendations concerning the economical compositions and disposition of protective barriers and devices for both scattered and direct radiation.

In contrast to the several outstanding improvements in film processing during the previous year, there has been only one during the present year. Replenishers that increase the life of X-ray developer with a considerable saving in cost have been presented to the trade.

X-ray technique and sensitivity has been subject to further refinements. The effect of secondary radiation upon the quality of the negative is one of the serious problems in industrial radiography. Lead screens appreciably reduce the amount of this undesirable radiation.

Industrial laboratories are always seeking opportunities to increase the sensitivity of the X-ray method. It has been reported that a sensitivity of 0.5% has been maintained in the commercial inspection of steel crankshafts with bearing sections 2 in. thick. A very extensive investigation by H. H. Lester of Watertown Arsenal has shown that in steel sections up to 3 in. thick, a sensitivity of 1% or less is generally obtained. Data on the effect of focal distance and secondary radiation on sensitivity and image delineation have been presented.

Electron Diffraction
an indispensable tool of research

By Lester H. Germer
Bell Telephone Laboratories
New York City

LAST YEAR in this journal I compared very briefly the diffraction of electrons with the diffraction of X-rays, and contrasted the uses in the field of metallurgy to which these two phenomena have been put. I pointed out the slight penetrating power of electrons, and the consequent application of electron diffraction to the investigation of the structure of thin films and surface layers in much the same way that X-rays are used to study the structure of metals in bulk.

Electron diffraction methods have not yet been taken over whole-heartedly by metallurgists, and I stated last year that researches in this field "have not yet proven of indispensable value" to those interested primarily in metals. Nothing at all, except those things that are necessary in order for life to exist, are actually indispensable; but the word "indispensable" can perhaps be applied to a tool or to a method which yields information not obtainable in any other way, and which at the same time has an immediate practical application, or at least satisfies an urgent demand. From the very first discovery of electron diffraction this method of investigation has given metallurgical information which could be obtained in no other way, but even last year the demand for this information was not such as to justify describing electron diffraction as "indispensable" to metallurgy.

During this year I consider that the situation has changed. Applications of electron diffraction have been extended to metallurgical problems of a practical nature in such a way that the method can now be considered definitely *indispensable* to the science of metallurgy. I shall very briefly mention one of these problems, point out developments which can be confidently expected in the near future, and speculate regarding an application which may be made in the coming years.

The branch of metallurgy in which electron diffraction methods are proving really indispensable, and that perhaps during only the last year, is the investigation of corrosion of metals and alloys by atmospheric gases at ambient and at elevated temperatures, and by various reagents under varied conditions. Much of this work is unpublished and is being carried out for commercial purposes. The successes already achieved are considerable and it appears that the future development will be very great, although the experimenters at present are few.

In the near future electron diffraction methods will compete effectively with X-rays in investigations of bulk materials. One can predict confidently that phase diagrams in alloys, and super-structures in atomic lattices, will be studied by electron diffraction. In these fields the slight penetrating power of electrons appears scarcely to be an advantage, but the extremely short electron wave-length gives high resolving power which is sometimes desirable, and the difference in experimental technique between the use of X-rays and the use of electrons often favors the latter.

Looking toward the future in a more speculative mood one wonders whether electron diffraction will not soon be a satisfactory tool for determining the arrangement of single layers of atoms upon solid surfaces. (One thinks at once of photoelectric cells and of chemical catalysis.) That this development is not at all improbable is evidenced by the fact that a number of successful determinations have been made of the arrangement of single layers of organic molecules. The study of smaller molecules and of atoms is more difficult, but a determined effort is being made to develop electron diffraction methods sensitive to still smaller amounts of material.

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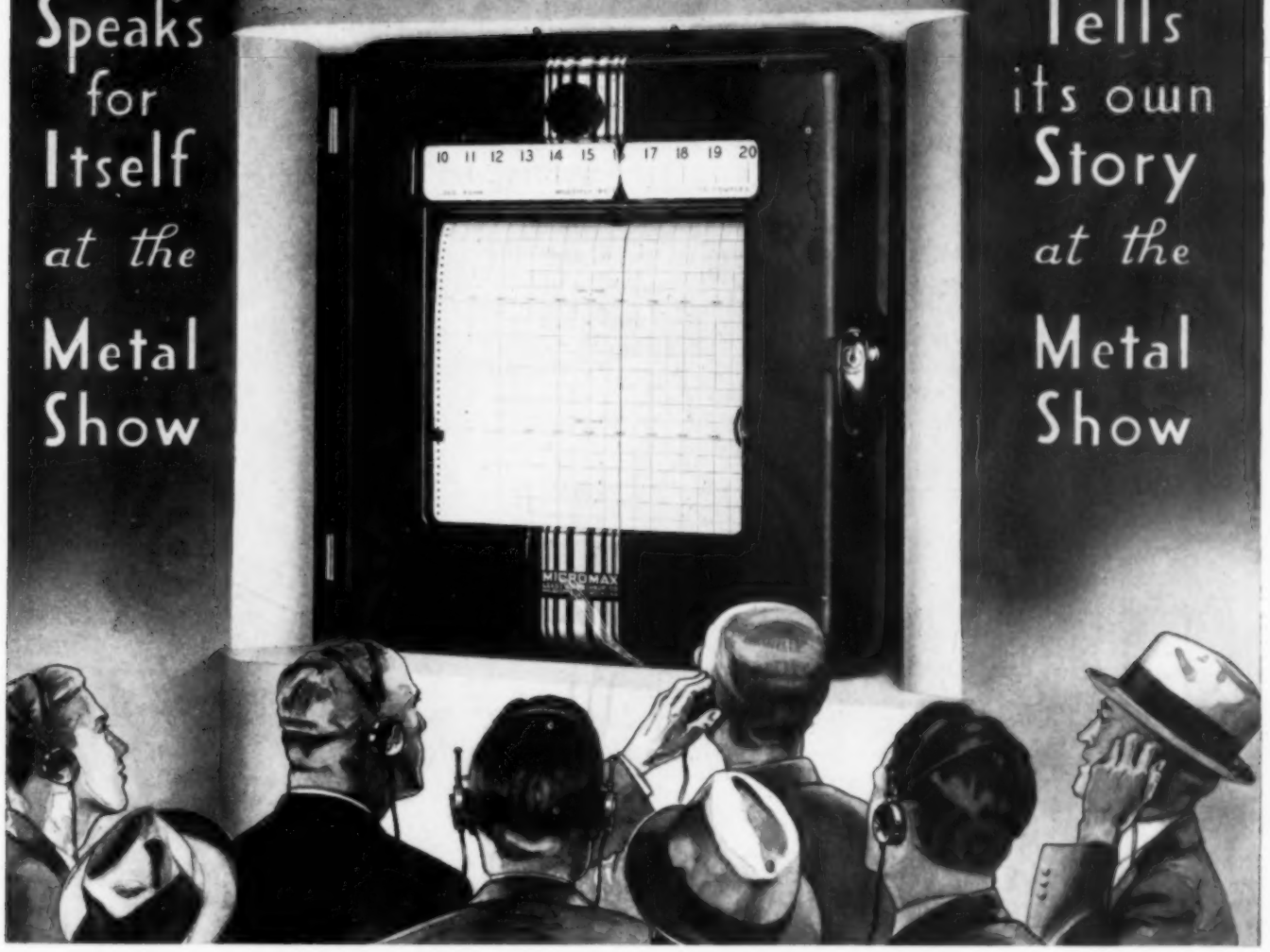

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Jrl Ad N-33(35)

Exposure Chart for Radiography of Steel

By Herbert R. Isenburger

St. John X-Ray Service, Inc., Long Island City, N. Y.

THESE DIAGRAMS are based on the following combination: Pulsating direct current tension generating equipment; line focus, grid action X-ray tube; high speed industrial intensifying screens; blue base safety film; 5 min. development at 65° F.; film density 0.7.

A solution is shown of this problem: "Find the correct exposure on 17-in. film at 36-in. focus-film distance for 3-in. boiler plate of density 7.85 using 220,000 volts and 8 milliamperes."

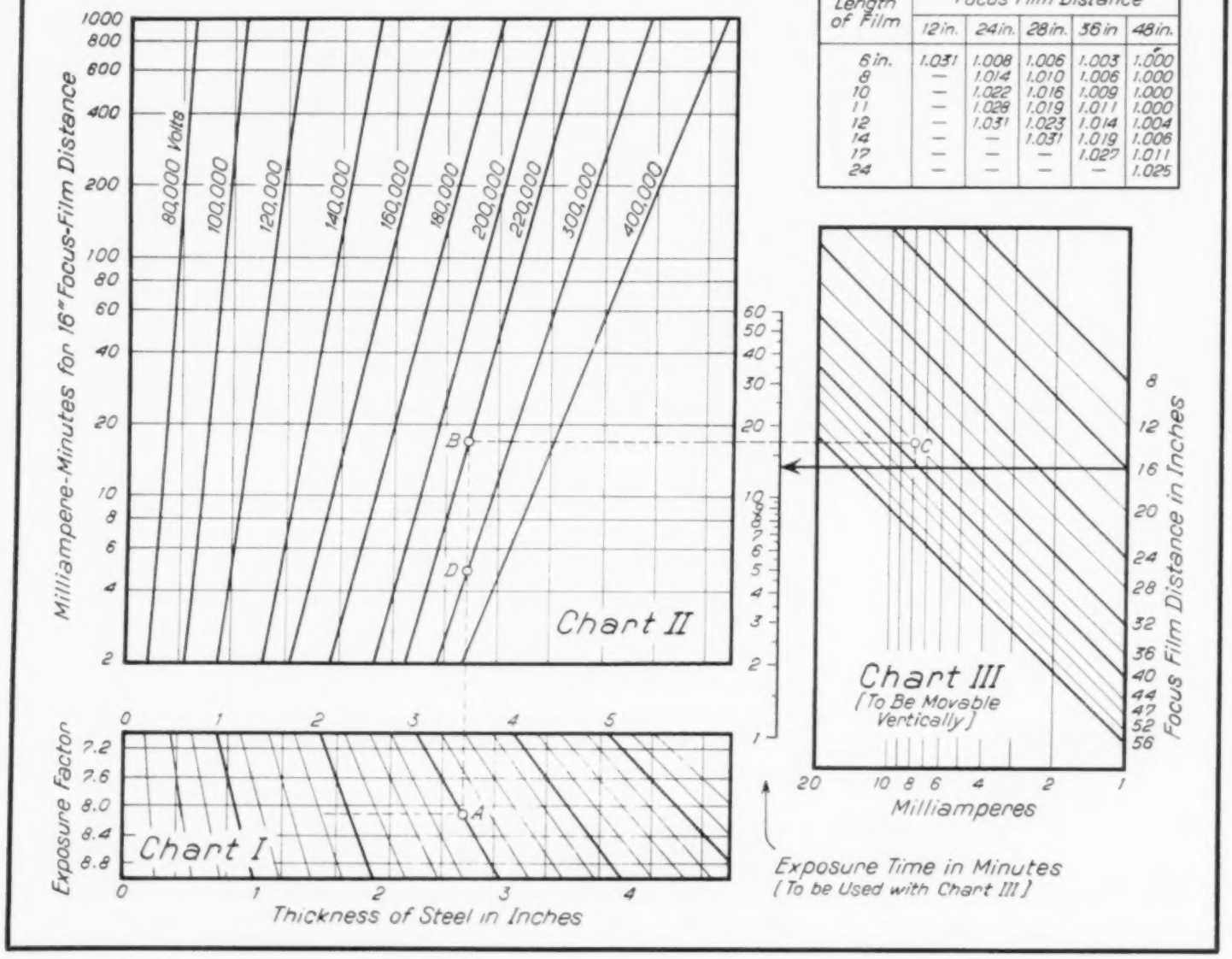
To compute the exposure factor at the ends of films of various lengths and at different focus-film distances, the factors shown in the table are multiplied by the actual density of the steel. In this example the factor 1.027 is located in the column for 36-in. focus-film in the line for 17-in. film. Multiply 1.027 by 7.85, the density of the steel to be radiographed, and the exposure factor is 8.1.

Find intersection of 8.1 with 3-in. line on Chart I (Point A), project upward to voltage of tube (Point B on 220,000-volt line in Chart II). Adjust Chart III so that Point C (corresponding to 36-in. focus-film distance and 8 milliamperes) is opposite Point B, and exposure time is read on central scale against arrow: 13½ min.

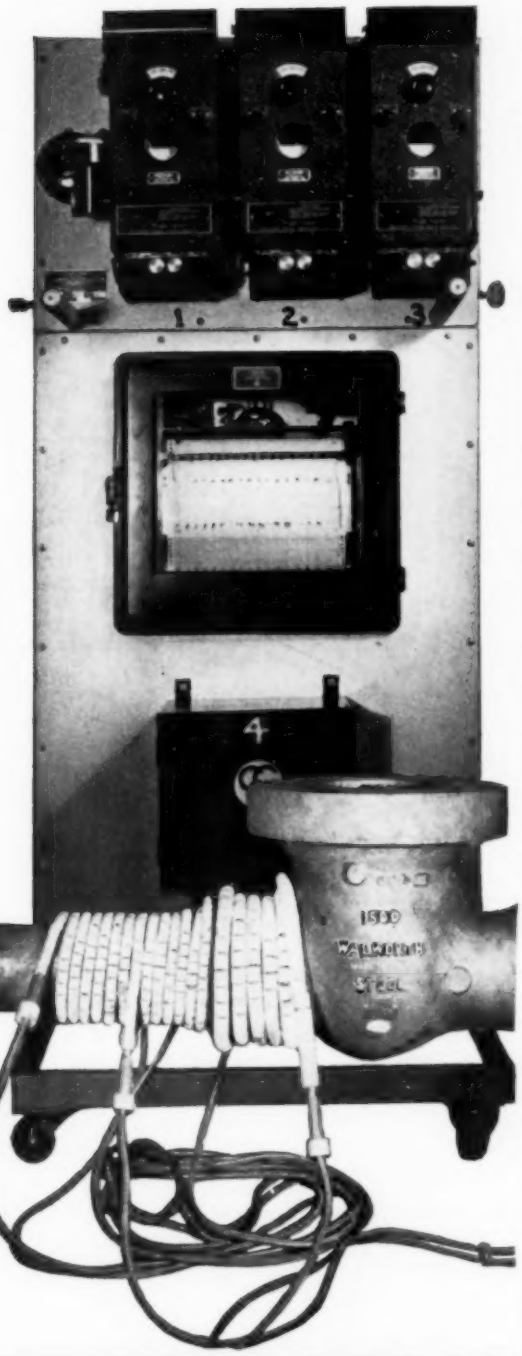
Scattered radiation must be filtered to get sharp definition above 250,000 volts, and the use of such filters requires increased exposure times as follows: 10% for 1½ to 2 in. of steel, 20% for 2 to 3 in., 40% for 3 to 4 in., and 50% above 4 in. For instance, suppose the conditions in the above problem remain the same, except a 300,000-volt source is to be used. Adjust Point C opposite Point D and exposure time is found to be 3½ min. without filter, which, increased 20%, comes to 4.2 min.

Table of Exposure Factors

Length of Film	Focus Film Distance				
	12 in.	24 in.	28 in.	36 in	48 in.
6 in.	1.031	1.008	1.006	1.003	1.000
8	—	1.014	1.010	1.006	1.000
10	—	1.022	1.016	1.009	1.000
11	—	1.028	1.019	1.011	1.000
12	—	1.031	1.023	1.014	1.004
14	—	—	1.031	1.019	1.006
17	—	—	—	1.027	1.011
24	—	—	—	—	1.025



listen"



THE PRODUCT

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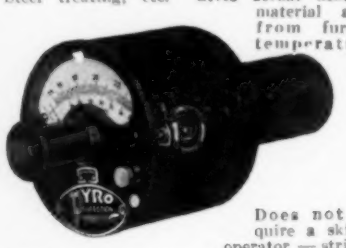

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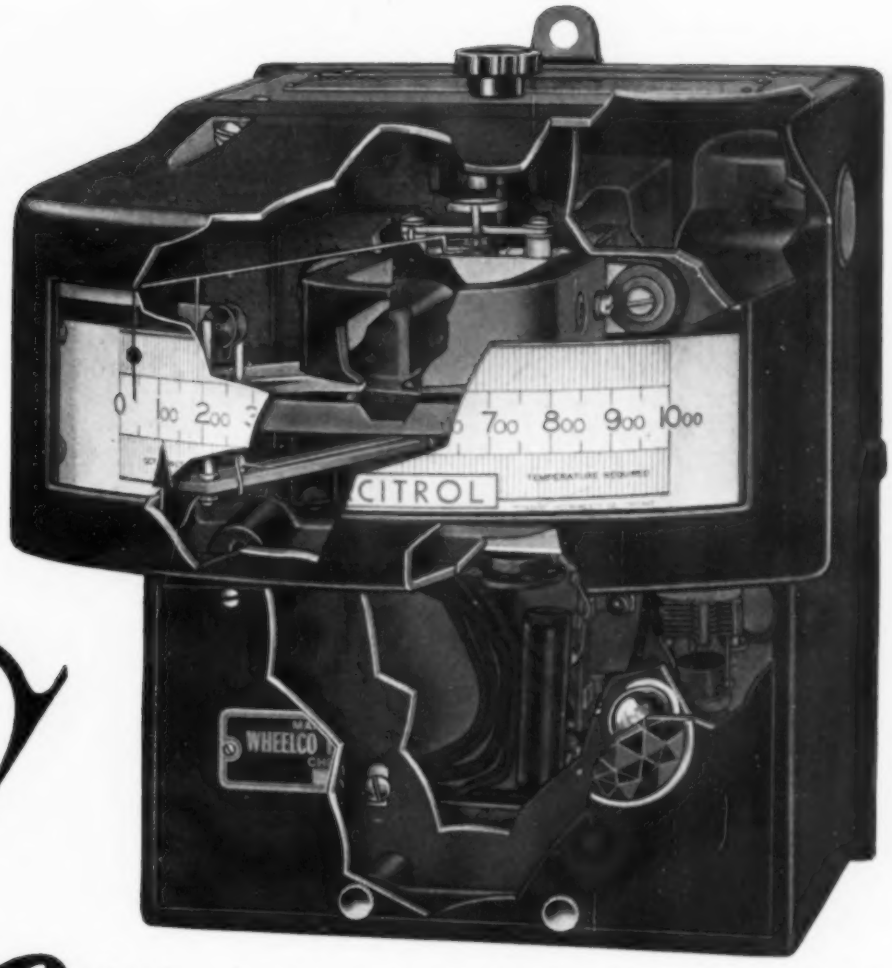

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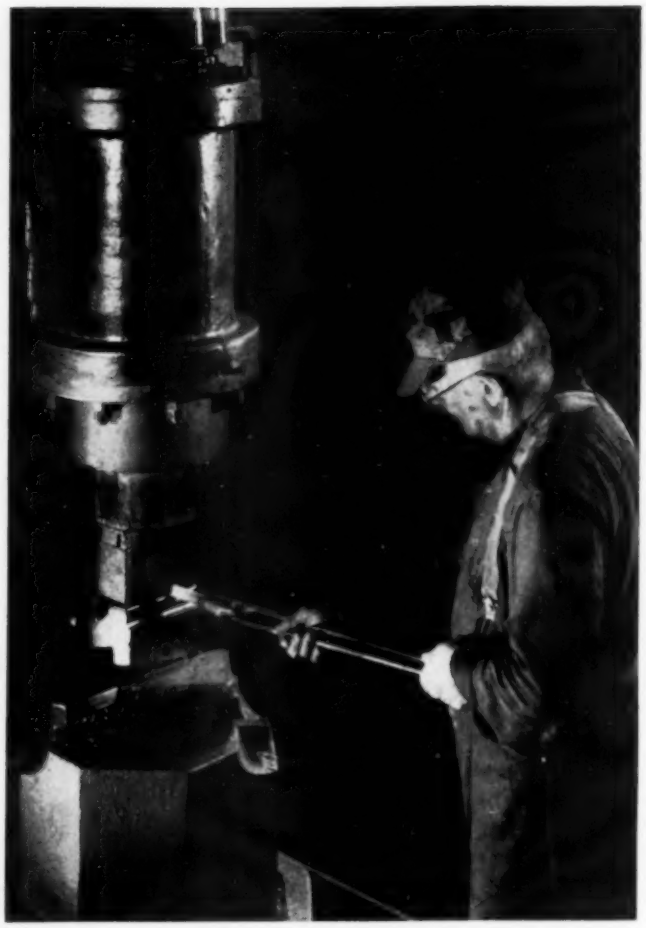

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For pneumatic chisels made of Bethlehem Omega Tool Steel, the recommended procedure is as follows:

Turn the shank from an annealed bar. Heat slowly to approximately 1800 to 1900 deg. F. and forge the cutting edge. Cool slowly. Heat the entire chisel to between 1600 and 1650 deg. F. and quench in oil. Temper to obtain a Scleroscope hardness of about 55, (approximately C43 Rockwell) throughout. Grind the shank to finish dimensions. Heat the thin cutting end of the tool to between 1600 and 1625 deg. F. for about 3 inches and quench the entire chisel in oil. If water is used, the quenching temperature should be about 1500 deg. F. Temper the entire chisel immediately at 450 to 550 deg. F.

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METAL PROGRESS OCTOBER, 1939

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Alloy Steels, Toolsteels, Carbon Steels, Castings

Engineering Steels

By Frank P. Gilligan
Past-President
Secretary-Treasurer, Henry Souther Engineering Co.
Hartford, Conn.

DISRAELI wrote: "Variety is the mother of enjoyment", and Cowper that "variety's the spice of life". If they were right in their interpretations, then the metallurgical observer of 1939 might reasonably conclude the American fine steel industry was leading a spicy but enjoyable life despite the paucity of profits. Its numerous varieties of compositions are becoming more and more multitudinous as they respond to the impact of grain size and hardenability specifications.

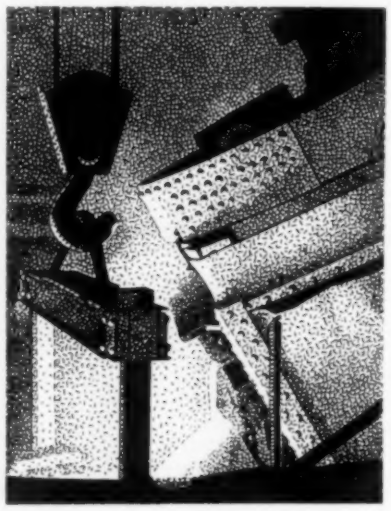
An eminent production executive assured us a few years ago that the steels of the current period are tailor made. Notwithstanding this sartorial perfection, official Washington gazes at the steel industry in a psychological cloud that is a hang-over from pre-war (1914 to 1918) days and threatens summary action because of the apparent absence of competition, oblivious of the fact that the research laboratories of both steel and alloy producers are providing strenuous, persistent and effective competition through improvements in quality controls.

The progress made possible by this research is translated into lower production costs in the customers' plants, and each steel and alloy producer hopes thereby to obtain an increasing share of the total volume of sales. The automobile industry is the outstanding exemplar of mass production, and it is in such plants that the fruits of this contest between the various mills and the various types of steel are most evident. For example, for many years the carbon-manganese (S.A.E. 1300) group of steels has been nibbling at the market originally belonging to the S.A.E. 3100, 4100 and 5100 steels, owing to the lower extra applying to this steel and to the attractive physical properties it offered. Persistent and successful efforts have been made to improve its uniformity of quality and physical characteristics.

Further advances seem probable for the near future. One of the most promising depends upon improved deoxidation practices. One process utilizes a deoxidizer containing vanadium, titanium and aluminum in chemical combination ("grainal"), the treatment being applicable to the individual ingots. Another process uses silicon, aluminum, vanadium and zirconium ("silvaz"). Considerable tonnage material has been processed with the first of these deoxidizers for actual production applications and to develop service experience. The static and dynamic test properties after heat treatment are intriguing. Improvement is attributed to the elimination of oxides and gases, as the residual alloy content is slight. As this "deluxe" carbon-manganese steel carries an extra that is substantially below those for the S.A.E. 3100, 4100 and 5100 steels — the competing alloy types — the coming months may

reveal further nibbling of the sales volume of these alloys.

All this does not mean that the long established S.A.E. alloy types are soon to be displaced by steels with lower alloy contents or by specially processed carbon steel grades. It does mean, however, that we shall have more varieties of steel before we have fewer — unless Mr. Hitler, unknowingly and vicariously, does for our steel business, by totalitarian methods, what it has not thus far been able to do for itself. It would be a serious mistake to lessen the varieties precipitously and by mandate rather than by evolution and the normal economic processes.



The basic S.A.E. steel compositions will continue to provide the metallurgical foundation in all those industries that utilize heat treatments in their production routine. The majority of users dislike having too many steels on their approved list, and where mass production methods are not utilized to the utmost, the steel user is slow to change, and will continue to use S.A.E. 3250 or some other S.A.E. composition for certain of his parts simply because he has been using it for the last 20 years with success and does not consider the estimated economies with a different steel warrant the risk of change. In other words, the great mass of steel users do not move with the celerity of the automobile producer. Not only are they more conservative, but they lack the volume that makes a slight change in metal cost so attractive.

The effort to make the road of the machine shop smoother (and more slippery) with lead additions has been successful in numerous applications. Nevertheless, enthusiasm for leaded alloy steels is not noticeable, and the coming year will probably find lead additions restricted more or less to the free cutting steels and to screw machine parts made of the lower carbon S.A.E. 1000 series.

In molybdenum steels, the alloy is being added in the form of molybdenum sulphide, with beneficial results from a machining standpoint and at no extra cost. More experience will be required in actual production before one can be sure the apparent benefits are not paid for indirectly in some sacrifice of essential physical properties.

These machining tests with leaded and other types of free cutting steels may yield industry unanticipated dividends. Some plants outside the automotive field have learned that their available equipment does not enable them to obtain the maximum machinability rates from the regular free cutting grades; consequently, when industry regains its confidence the domestic machine tool builder should find an increased demand for those tools that promote lower machining costs.

Hardenability ("Jominability") bids fair to become the newest factor in the purchase order of the steel consumer of 1940. While grain size control is now more or less general, the hardenability test is due to have a thorough try-out in practically all plants where metallurgical control is an important factor in the production system.

We shall, therefore, probably have a very active "social season" the coming year, as the steel mill metallurgist endeavors to enlighten the metallurgist, the purchasing agent, and the steel treater as to the proper procedure for hardenability tests. How simple and happy seem the days of hot acid etch, as compared with these days of magnaflux and Jominability!

Grain Size

By Martin Seyt
Tetragonal Lattice Mfg. Industries, Inc.

OUR BUSINESS is to manufacture tetragonal lattices to fill three-dimensional space (plug!) so we were non-plussed by a request to fill quadragonal space in METAL PROGRESS on the subject of the future of grain size. We therefore referred the matter to our capable office assistant, a shapely Young Thing who recently won the title "Miss Pre-Vision of 1939". Consulting the Occult Crystal Sphere (made of Cr-Ni-V-Mo-W steel, grain size 2 to 7), she came across with the following:

"I seem to see a considerable number of hairy apes — no — they're — ah — I see now,

they are metallurgists. They are congregated around a pile of jumbled articles — let me see — oh, it is a mound of crankshafts, microscopes, polishing cloth, A.S.T.M. grain size standards, and steering knuckles, all drenched with alcoholic picric acid. They are digging — digging — digging — what's that? At the bottom of the pile is Information — no — two Informations — no — no — three Informations. Put a little Canada Dry ginger ale in mine — no, I'll take it straight — we're coming to the hard part.

"Ah, that's better!

"Information No. 1: Most of the hairy a . . . . — the metallurgists — have in the past thought that aluminum oxide was the only thing to consider in restricting grain growth — in the future the action of carbides particularly in high-carbon steels and other compounds will receive more of the quantitative study lavished so richly in the past on aluminum alone.

"Information No. 2: I said this last year in winning my present title (isn't it a nice silver loving-cup, boys? — fill it up again, you rats) — there will be a beautiful campaign to study more quantitatively the relationship between grain size and hardenability; quantitative data are all too meager, and I see a big crowd gathered around the diggers — the crowd has a 'lean and hungry look' — they're the fabricators and engineers who wait for Information while the hairy metallurgists theorize about atoms or attend conc . . . . — conc . . . . — conclaves. That's it — the crowd is about to konk the diggers on their skulls unless the information is forthcoming. And now, ah, what's this — I see a frenzy of activity — they're all crowded around

"Information No. 3, so it's a bit hazy, but it looks like 'Campaign of the Future' — it is — yes — it's an opera, scored for strings (tempered steel wire), kettle drums (look like lead pots for heat treating), harps (alloy cast iron frame) and French horns (Osmond-Chatelier type). The theme is a campaign in which Baron Inherent arrived on the scene early, and almost took away the Princess, the incomparably lovely Graina Siza; but the hero, Count Properly, awakes from his deep sleep just in time, and in a mighty Agenda (in which the great chorus joins) saves the Princess so that she may wisely and justly rule her people, who ever after consider her numerous name-sakes, grain sizes, as fascinating and ever-changing tools to be devoted to the service of mankind.

"Take it away, boys."

Toolsteels

By James P. Gill
President-Elect and Metallurgist
Vanadium-Alloys Steel Co., Latrobe, Pa.

IT IS NOT EASY to describe the advances that have taken place in the metallurgy of toolsteels within the last year, since such advances are made up of a great number of small changes, none of which considered individually would be particularly significant. However, they have gone forward on all fronts, including improvements in methods of manufacture, in composition, and in heat treatment.

Manufacturers have always been faced with difficulties in preventing decarburization of hot rolled bars, a problem which during the last several years has neared solution. This is of considerable economic importance to the tool manufacturer, since it decreases the amount of material that must be removed from the surface of hot rolled bars. Manufacturers have continued to improve the uniformity of carbon toolsteels so that such materials are obtainable which will harden with any one of several case depths yet have a grain size No. 9 or finer.

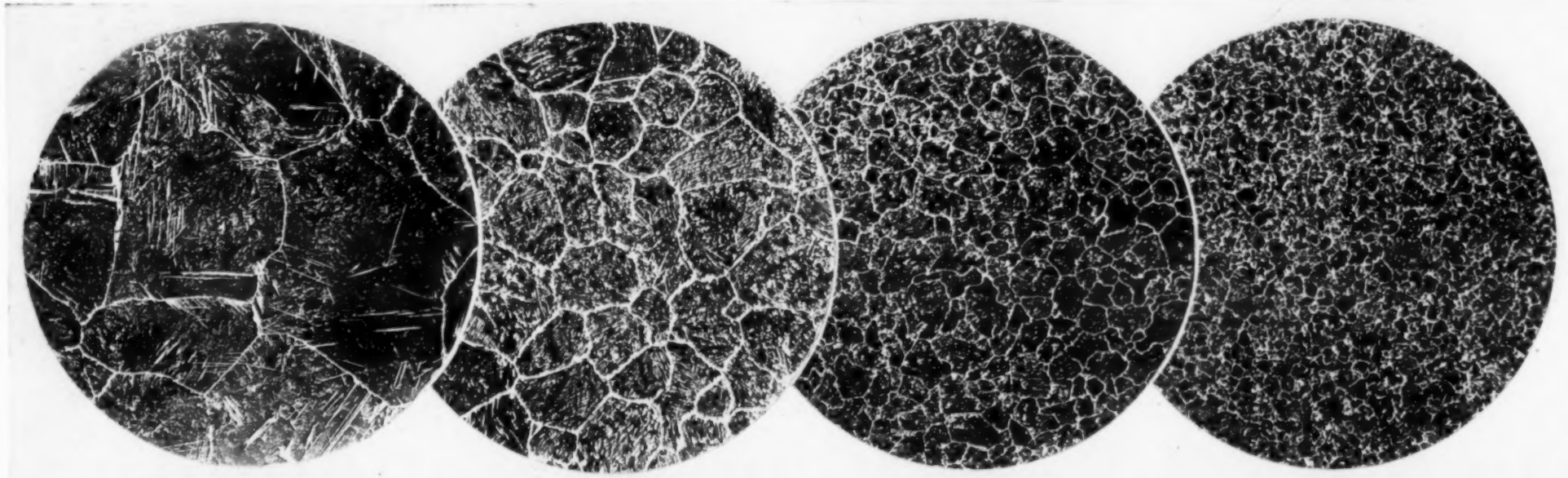
The introduction of new compositions as well as slight changes in the composition of the older types of toolsteels continues. Small amounts of molybdenum have been added to a number of die steels to obtain greater ease in hardening. Molybdenum has proven particularly valuable as an alloying element in such steels as it permits an increase in the size of tools and dies that can be made of oil and air hardening analyses. Die steels of the composition characterized by about 5% chromium and 1% molybdenum, which can be satisfactorily hardened by cooling in still air in comparatively large sections, have continued to increase in popularity; the grade with about 0.30% carbon is generally used for hot work and the grade with about 1% carbon for cold work.

It is in the field of high speed steels that introductions of new compositions have continued in greater number than all the others combined. Possibly the two most outstanding developments in compositions within the last year have been an 8% molybdenum high speed steel containing no tungsten, about 4% vanadium and 1¼% carbon, which has shown remarkable resistance to wear. The other type of high speed steel has been one characterized by both tungsten and molybdenum in about

Standard Grain Sizes for Steels

Carburized and slowly cooled to develop cementite network. Magnified 100 diameters. Micros courtesy Timken Roller Bearing Co.

Grain Size No. 1; Up to 1½ per sq.in. No. 3; 3 to 6 grains per sq.in. No. 5; 12 to 24 grains per sq.in. No. 7; 48 to 96 grains per sq.in.



No. 2; 1½ to 3 grains per sq.in. No. 4; 6 to 12 grains per sq.in. No. 6; 24 to 48 grains per sq.in. No. 8; More than 96 grains per sq.in.

equal amounts, usually from 4 to 6%, with the usual amounts of chromium and vanadium.

Most of the progress in the heat treatment of toolsteels continues to be motivated by the desire to protect the surface of the tool during heating operations to prevent not only carburization or decarburization but also to produce a bright finish. Several new types of salts have been introduced for which considerable claims have been made, and there has been at least one new type of furnace using a radically different atmosphere.

It is easy to be badly mistaken in attempting to foretell what the immediate advances may be in any field of technology, but within the field of toolsteels the progress that is to be made during the next several years is likely to follow about the same pattern of steady progress we have seen during the last year or two.

Hard Cemented Carbides

By Gregory Comstock
Metallurgical Consultant, New York City

DURING the past twelve months, the following appears to summarize activity in the field of hard cemented carbides:

This period may be generally described as having been one of consolidation.

American manufacturers of these materials have generally reviewed their production procedure from raw material to finished product, have taken the necessary steps to provide adequately for increased quantity production on as economic a basis as possible, and have otherwise prepared themselves for the larger application of these tool and die materials in quantities more nearly approximating their European usage.

Uses of the hard cemented carbides in their present forms have now been quite generally established. Their place in the industrial scheme is fortunately no longer a matter of expensive exploration and conjecture. Certain applications are naturally more decisively advantageous for the present forms of cemented carbides than are others. One of their greatest possibilities — the machining of steel — has presented the greatest difficulty, and still is the major objective of research and development. For this use the trend has been toward the incorporation of varying amounts of titanium carbide with the basic tungsten carbide and cobalt compositions. Tantalum carbide has been similarly employed. Results of such modified mixtures have been distinctly encouraging, and the general usefulness of the hard cemented carbides has been considerably augmented by the knowledge accumulated. The more recent developments appear to indicate that minor amounts of these additives are more desirable than their presence as major constituents of steel cutting compositions.

There apparently exists a difference of opinion as to the mechanics involved in the incorporation of titanium carbide with tungsten carbide (and the auxiliary binding materials of this type of sintered products). One school of thought advocates the formation of definite compounds such as $WTiC_2$; another the development of a "mixed crystal" of the hard components — the name deriving from the *misch-kristall* of German parlance. The point appears to be rather an important one from the patent, development and production viewpoints, and its establishment is anticipated in the relatively near future.

Future developments present, as always, an intensely interesting and potentially important field of speculation. All the present forms of these products are primarily based on the strength, hardness and highly metallic characteristics of the carbide of tungsten and its capacity for being cemented in a thermally stable alloy matrix. A decade of the most intensive experimentation has not materially changed this conception nor basically altered the final products, although the technique of their production and the use of what might be called alloying additives have most certainly contributed greatly to practical applications.

Increased general use and industrial development of the processes of powder metal-

lurgy in other and quite different fields, and the new knowledge of the possibilities which it demonstrably presents for new departures from established metallurgical procedure, may contribute something to the future development of the hard cemented carbides. Indeed it would be strange if this did not occur! It is felt that these developments may quite reasonably result in the ultimate appearance of new types of super-tool, super-die and super-cutlery materials which lie within a field intermediate between the cast materials and the hard cemented carbides as we know them in their present forms today. This also is a major objective in current research.

Plastics Versus Metal
particularly sheet metal

By Motor Observer
Detroit, Mich.

PERHAPS one of the most dramatic phases of progressive engineering is the never-ending competition between different forms of materials. And in this respect automotive circles have been watching with interest the current developments in plastics which promise to provide keen competition for sheet metal in applications where stampings have heretofore had a logical and undisputed sway.

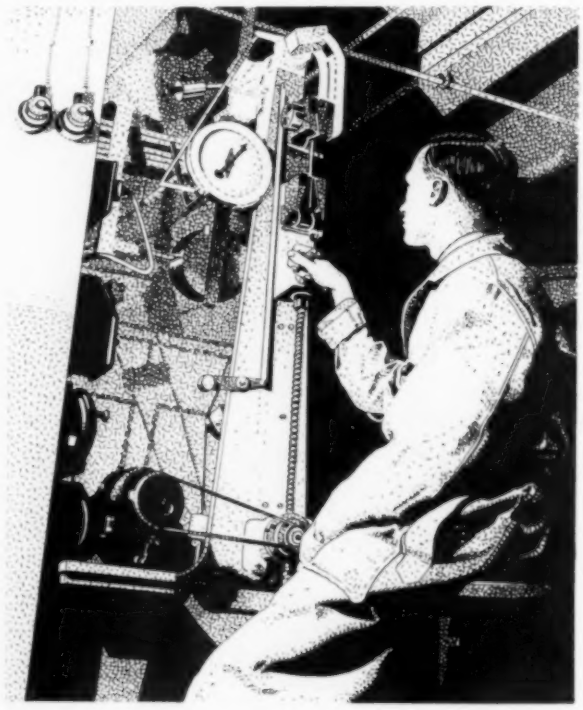
Up to the present time the automotive field has enjoyed the fruits of plastics developments primarily in decorative effects, although recently certain types of transparent plastics such as clear "lucite" and various pigmented materials have been replacing the red or amber glass in tail-lamps, while clear substances have replaced glass in instrument panels on a rather broad scale.

Too, there have been several outstanding examples of plastic castings replacing sheet metal assemblies. Most interesting was the large "bakelite" instrument housing, of approximate cylindrical form, used by Oldsmobile in 1938. Several passenger car builders have used large or small plastic sections in instrument panels, in some cases replacing corresponding sheet metal sections. Latest practice, however, as exemplified by Packard, is to use large sections of plastics — even comprising the entire panel — strengthened and supported by a sheet metal back.

Particularly during the past year, there has been a persistent development of special plastic compositions employing various types of synthetic resins, intended to replace sheet metal in parts where structural strength rather than decorative appearance is of prime importance. For many years there has been a hushed discussion of the possibility that entire automobile bodies may be so fabricated. None of the early experiments had much practical value, and even today there is considerable skepticism as to its desirability or practicability.

Confidential reports now appear to indicate the availability of new plastic compositions possessing thermo-setting properties which promise high tensile strength, freedom from ordinary brittleness, and unusually good elastic properties. It is even rumored that one prominent manufacturer proposes to make certain large sheet metal panels — such as a trunk lid or hood top panel — from a unique plastic formula. If and when this is accomplished, perhaps even in 1940, such plastic sections will be unobtrusive, finished in body color.

In other fields such as household accessories, small radio cabinets, bottle closures, and innumerable gadgets, plastics are no novelty, and many times are used instead of sheet metal. But in automotive construction where every portion of the structure, both exterior and interior, is subject to the ravages of the weather and to extraordinary abuse, encroachment of plastics as a metal-replacing medium has been a very gradual process.



So far as one can see at the moment, plastics cannot offer serious curtailment in the use of sheet metal for panels and assemblies until the present pioneering effort has been consummated. Everyone concerned will watch with close interest the first application of plastics to body construction, since any successful service and production history is bound to have far-reaching implications.

It may be said, finally, that the recent sporadic discussions of experimental structural plastic applications both in the United States and abroad cannot be given the same importance as the actual production applications which apparently are in the offing.

Sheets and Sheet Mills

By J. Hunter Nead
Chief Metallurgist, Inland Steel Co.
East Chicago, Ind.

IT WOULD PROBABLY be redundant to dwell on the development of the wide continuous hot and cold strip mills; so much has been written about the subject already. After the initial bold idea of rolling strip steel was put into practice, the development of these mills is principally a record of mechanical and electrical achievement. The greatest incentive toward wider sheets was probably the demands of the automobile industry, which was and still is in a highly competitive condition. The yearly change of car models, with the demands for sheets of better and better drawing quality to meet the requirements of streamlining, and for larger sheets so that fabricating operations could be reduced in number and cost, has been the principal driving force.

At the present time sheets up to 98 in. wide have been made possible by the construction of suitable mills. In other words, one of the principal demands of the buyer, that for size, is very close to being satisfied by the mills at present.

Mechanically, also, the present sheets are meeting close tolerances in the essentials of gage, weight, length, and width. The type of sheet surface is also mechanically regulated to suit the requirements of any particular job, be it a smooth bright surface for tinning, matte surface for enameling, or a dulled surface for certain types of deep drawing. It may be said here that the development of dulled or blasted surface rolls, with which a dull surface is imprinted on the sheet, has been one of the most important in the strip industry.

The problem of furnishing sheets of sufficiently high quality to meet the increasing demands of modern designing, however, remains. At present and from now on the pressure and development in sheet and strip mills, we believe, will be principally in the auxiliary mill equipment and processes (such as annealing) and the production of special steels and specially processed sheets to meet the demand for increased quality.

Auxiliary equipment which is undergoing changes and in which further development is imperative includes annealing equipment and processes, the production and maintenance of correct furnace atmospheres, production of uniform deoxidizing gases, and the development of uniform annealed properties and structures in the wide sheets being used at present.

In the beginning of modern sheet and strip mills, gas-fired and oil-fired batch, pit and tunnel furnaces were standard. One of the latest developments in the past few years has been the portable, gas-fired radiant tube, annealing covers. These have added considerably to the flexibility and efficiency of operation as well as doing good, uniform annealing. General Electric's bell type furnaces have been applied to annealing of strip coils at some plants, providing the greatest departure from past methods.

Bright annealing and normalizing furnaces are being experimented with and used with varied success.

While remarkable work is being done with the present equipment, there has not been the development of annealing and annealing processes along quality lines that there possibly should have been — certainly not an advance comparable to that of the mills proper.

Until fairly recently the desired deep drawing quality and good surface sheets were obtained within a standard analysis of rimming steel of say 0.04 to 0.12% carbon; 0.25 to 0.50% manganese; low phosphorus and sulphur and low residual alloys. In the past few years the "stabilized non-aging" killed steels (essentially a higher cost product) which have been developed by several producers, have been meeting a remarkable degree of success in some severe deep drawing operations as well as in applications which make full use of the non-aging properties. Although these steels do not represent anything new in steel making, since

Classification of American Toolsteels — I

Adapted from Tool Steels, by James P. Gill

General Purpose Carbon Toolsteels

Water hardening; low wear resistance; high warpage; no red hardness; shallow hardening

Carbon	Silicon	Manganese	Sulphur	Phosphorus	Vanadium	Common Uses
0.60-1.25 (a)	0.15-0.50	0.10-0.35	0.03 max.	0.03 max.	Note (b)	Almost universal; note (c)

(a) Usually subdivided by 0.10% steps; for instance 0.65-0.75%, 0.75-0.85%, etc.

(b) Plain carbon steels have no vanadium; carbon-vanadium tool steels may have from 0.08 to 0.40% vanadium, depending on grade.

(c) In lower carbon ranges the steels make shear blades, hammers, striking dies, rock drills. In medium ranges of carbon, the steels make chisels, smith's tools, dies, and cutters for machine tools. In the higher ranges of carbon are small cutters, wood workers' tools and cutlery.

Chromium-Vanadium or Low Chromium Toolsteels

(Substitutes for carbon tool steels)

Mostly water hardening; low wear resistance; high warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Vanadium	Remarks
0.50-1.40	0.15-0.50	0.10-0.35	0.10-0.25	.....	Chromium corrects tendency toward soft spots
0.50-1.40	0.15-0.50	0.10-0.35	0.25-0.50	.....	More intense hardness
0.50-1.40	0.15-0.40	0.10-0.35	0.60-1.20	0.10-0.20	Water hardening } Very tough in low carbon ranges
0.50-1.40	0.15-0.40	0.40-0.60	0.60-1.20	0.10-0.20	Oil hardening }

High Carbon, Low Tungsten Tool and Die Steels

(Finishing tools for hard steels or non-ferrous alloys)

Oil hardening; medium wear resistance; medium toughness; low warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Tungsten	Vanadium (Optional)	Remarks
0.90-1.10	0.20-0.40	0.15-0.30	.....	1.00-1.50	.....	Somewhat erratic in heat treatment
1.15-1.25	0.20-0.40	0.15-0.30	.....	1.75-2.50	0.10-0.25	
0.90-1.10	0.20-0.40	0.15-0.30	0.35-0.75	1.50-2.50	0.10-0.25	Water hardening } more dependable
1.15-1.30	0.20-0.40	0.15-0.30	0.35-0.75	1.50-2.50	0.10-0.25	Oil hardening }

Manganese Oil Hardening Die Steels ("Non-Deforming")

(General purpose tools and especially dies, punches and broaches)

Oil hardening; low wear resistance; medium toughness; low warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Tungsten	Molybdenum	Vanadium	Remarks
0.85-0.95	0.20-0.40	1.50-1.75	.....	.....	.....	0.10-0.25	More subject to grain growth
0.85-1.00	0.20-0.40	1.15-1.45	0.30-0.60	0.30-0.60	.....	0.10-0.25	Corrects above, but hardness is lower
0.85-1.00	0.20-0.40	1.35-1.65	.....	.....	0.20-0.35	0.10-0.25	Attains highest hardness
0.90-1.00	0.20-0.40	0.90-1.15	0.50-0.90	.....	.....	.....	Least susceptible to hardening cracks

Tungsten Alloy Chisel and Punch Steels

(Oil hardening steels; shears and battering tools for cold metal; heading dies)

Medium wear resistance; high toughness; low warpage; medium red hardness; medium deep hardening

Carbon	Tungsten	Chromium	Vanadium	Silicon	Remarks
0.45-0.60	0.75-1.25	0.75-1.25	.....	1.00-1.50	Good wear resistance but somewhat brittle
0.45-0.60	1.50-2.00	0.75-1.25	.....	1.00-1.50	Higher tungsten improves wear resistance
0.45-0.60	1.00-1.75	0.50-1.00	.....	.....	Low silicon increases toughness 25%
0.40-0.55	1.75-2.25	0.75-1.25	0.10-0.30	.....	Most popular analyses, tough and fine grained
0.55-0.65	1.75-2.25	0.75-1.25	0.10-0.30	.....	

Tungsten Finishing Toolsteels and Drawing Dies

(Brittle but intensely hard and keen edges for cutting hard materials)

Water hardening; medium wear resistance; low toughness; high warpage; no red hardness; deep hardening

Carbon	Tungsten	Chromium	Remarks
1.20-1.40	5.00-6.00	.....	Slightly better wear resistance than lower tungsten } High movement; best for drawing dies
1.20-1.40	3.00-5.00	.....	Slightly tougher than higher tungsten } that must be rehardened after wear
1.20-1.40	4.00-6.00	0.40-0.80	Chromium improves heat treatability and reduces volume change
1.20-1.40	4.00-6.00	1.00-1.50	

Silicon-Manganese Punch and Chisel Steels

(A water hardening and inexpensive steel for cold cutting)

Medium wear resistance; medium toughness; medium warpage; medium hot hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Molybdenum	Vanadium	Remarks
0.50-0.60	1.80-2.20	0.60-0.90	.....	.....	.....	Spring steel analysis; all high silicon steels liable to soft skin
0.60-0.75	1.70-2.25	0.70-0.90	.....	.....	.....	More carbon gives higher hardness
0.50-0.60	1.75-2.25	0.70-0.90	0.20-0.35	.....	0.15-0.30	Alloys increase hardenability and refine grain
0.50-0.60	1.75-2.25	0.70-0.90	.....	0.40-0.60	.....	Molybdenum greatly increases hardenability
0.50-0.60	0.75-1.25	0.35-0.60	0.20-0.40	0.40-0.60	.....	Low silicon reduces brittleness and wear resistance

Classification of American Toolsteels — II

Adapted from Tool Steels, by James P. Gill

High Carbon, High Chromium Punch and Die Steels

(Durable rolls, mandrels, punches, dies and shears for cold work)

High wear resistance; low toughness; low warpage; high hot hardness; deep hardening, difficultly machinable

Carbon	Chromium	Vanadium	Molybdenum	Cobalt	Nickel	Remarks
			Oil Hardening Types ("Non-Deforming")			
2.25-2.45	12.00-14.00	.....	.....	.....	.....	
2.10-2.20	12.00-14.00	0.75-1.00	.....	.....	.....	Somewhat tougher
2.15-2.25	12.00-14.00	.....	.....	.....	0.50-0.75	Slightly air hardening; most difficult to machine
2.15-2.25	12.00-13.00	0.75-1.00	.....	0.60-1.00	.....	Slightly red hard
			Air Hardening Types (Tougher Than Above; and Deform Less in Hardening)			
1.40-1.50	12.00-13.00	.....	0.50-0.60	3.00-4.00	.....	Red hard properties. Good for cutting tools on non-ferrous materials
1.50-1.70	16.50-18.00	.....	.....	.....	.....	Liable to harden non-uniformly
1.50-1.60	12.00-13.00	.....	0.80-1.00	.....	.....	
1.50-1.60	12.00-13.00	0.80-1.00	0.75-0.90	0.40-0.60	.....	Vanadium imparts greater toughness
1.40-1.55	12.00-13.00	0.80-1.00	0.75-0.90	.....	0.60-0.80	Most difficult to machine

Chromium Die Steels for Hot Work

(Gripper, bending and heading dies for light work up to 600° F.)

Air or oil hardening; medium wear resistance and toughness; low warpage; medium hot hardness; deep hardening

Carbon	Chromium	Molybdenum	Remarks
0.85-1.00	3.75-4.00	.....	Usually quenched in light air blast
0.85-1.00	3.25-3.75	.....	Lower chromium reduces cracks during oil quenching
0.65-0.75	3.75-4.25	.....	Oil quenching (lower carbon) but not as rigid at 500° F.
0.85-1.00	3.75-4.25	0.40-0.60	Best air hardener

Tungsten Die Steels for Hot Work

(Blanking, forming, extrusion and casting dies to work up to 1100° F.)

Air or oil hardening; medium wear resistance; medium toughness; low warpage; high red hardness; deep hardening

Carbon	Tungsten	Chromium	Vanadium	Remarks
0.25-0.35	8.00-10.00	2.50-3.50	0.30-0.60	In most general use; serviceable up to 1000° F.
0.35-0.45	8.00-10.00	2.50-3.50	0.30-0.60	Higher carbon gives higher hardness
0.40-0.50	9.00-12.00	1.25-1.75	.....	Chromium lowered to increase toughness
0.25-0.35	12.00-16.00	2.50-3.25	0.30-0.60	Increased tungsten raises serviceability to 1100° F.
0.35-0.50	12.00-16.00	2.50-3.25	0.30-0.60	Hardenability and brittleness rises with carbon content
0.50-0.60	12.00-16.00	2.50-3.25	0.30-0.60	
0.50-0.60	17.00-19.00	3.00-4.50	0.60-1.20	Low carbon, high speed steel

Tungsten-Chromium Steels for Hot Work and Die Casting Dies

Air or oil hardening; medium wear resistance; good toughness; low warpage; high red hardness; deep hardening

Carbon	Tungsten	Chromium	Vanadium	Molybdenum	Silicon	Remarks
0.40-0.50	6.50-7.50	6.50-7.50	0.20-0.60	.....	0.30-0.80	Maximum alloy for hottest services (1000° F.)
0.35-0.45	5.50-6.50	5.00-6.00	.....	.....	0.30-0.80	Tougher
0.30-0.40	0.75-1.25	4.50-5.00	.....	1.00-1.50	0.80-1.00	Less expensive substitute
0.35-0.40	.....	4.50-5.00	.....	1.00-1.50	0.80-1.00	Properties similar to steel above

High Speed Steels

(Cutting tools of all types; tools for severe hot work)

Air or oil hardening; high wear resistance; low toughness; low warpage; high red hardness; deep hardening

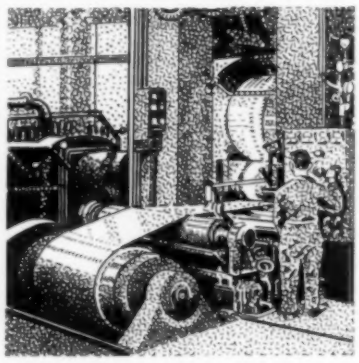
Carbon	Tungsten	Chromium	Vanadium	Molybdenum	Cobalt	Remarks
			Conventional Types			
0.55-0.75	17.00-19.00	3.50-4.50	0.75-1.25	.....	.....	Most used; brittleness and cutting properties vary directly with carbon content
0.55-0.75	19.00-21.00	3.75-4.50	0.75-1.25	.....	.....	Better cutting ability but more brittle
0.75-0.85	17.00-19.00	3.50-4.50	1.75-2.25	0.40-0.90	.....	Best cutting ability; excellent for finishing cuts
0.55-0.75	13.00-15.00	3.50-4.50	1.75-2.25	.....	.....	Roughing tools; somewhat erratic in hardening
			Molybdenum High Speed Steel			
0.60-0.85	1.00-2.50	3.50-4.50	0.75-1.25	6.00-8.00	.....	Less expensive; "strategic" alloying element used
0.70-0.90	.....	3.50-4.50	1.75-2.50	6.00-9.00	.....	Improved by high vanadium content
			Cobalt High Speed Steel			
0.65-0.80	17.00-19.00	3.50-4.50	0.75-1.25	.....	3.50- 5.00	For cutting hard, gritty or tough materials
0.65-0.80	17.00-19.00	3.50-4.50	1.50-2.25	0.50-1.00	6.00- 9.00	Cutting ability varies as total alloy content
0.65-0.80	18.00-21.00	3.50-4.50	1.75-2.25	0.50-1.00	10.00-13.00	Maximum alloy to be forgeable
0.65-0.80	12.00-15.00	3.50-4.50	1.75-2.25	.....	5.00- 8.00	Good service on special jobs

non-aging steels have been made for many years both in this country and abroad, they do indicate a departure from orthodox practice in sheet steel. An experimental development of sheets containing a fractional percentage of lead ("ledloy") for a job requiring softness and at the same time good cutting and shearing properties, was completely successful, and may be cited as another example of modern trends. In the future we may expect more of a similar nature.

Cold strip tin plate is a fairly recent development and considerable outlay for new tinning and rolling equipment has been made. Electrolytic tinning of plate has given indications of being successful, and we may confidently expect to hear more of it in the future. Developments in galvanizing continuous strip and changes in methods of galvanizing may be looked for also.

Although radical developments may be expected in the future it does not mean that the potentialities of the present equipment, processes and steels have been exhausted by any means. Knowledge concerning the inter-relation of various phases of hot strip operation, such as finishing temperature, finishing conditions, coiling, the use of sprays, drafting and gage, and factors of the cold reduction process such as the amount and kind of reduction, annealing times and temperatures, has been accumulated by both experimentation and practical experience. The net result is a better control of uniformity in the product.

While attention has been principally focused on strip mills and strip products, the single stand two-high and three-high sheet mills have also undergone a marked modernization, resulting in much better sheets as regards gage and surface, produced at a lower cost than was previously possible. This came about by the use of coil breakdowns instead of the old type sheet bar, the installation of semi-automatic pack weighing machines, semi-automatic doublers, continuous pack heating furnaces, automatic catchers, and the use of conveyor systems. In fact progress has been such that the single stand sheet mill has a definite place in the industry. The prediction that this type of mill would be driven out of business by the continuous strip mills has not been carried out.



Cold Finished Steels

By E. L. McReynolds
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Republic Steel Corp., Massillon, Ohio

MACHINABILITY is one property of cold finished bars which is receiving a lot of attention today. All of the cold finishers are concentrating on this problem and the future will see many changes in steel making, resulting in its improvement. Some of the cold finishers have automatic screw machines running almost continuously on special steels in an effort to discover something that will give better machinability. Such efforts have made the hot mills "machinability conscious", and credit should be given the cold finishers for the continuous improvement.

Many cold finished bar items are made for one customer and for one job. There is every reason to believe that this type of business will increase. Close contact between producer and consumer is required. By improvements in engineering, some users now find that cold drawn steel can be applied where previously the parts were quenched and drawn. Low temperature annealing after cold drawing (so-called stress relieving) is very applicable here and good physical properties can be had. By varying the amount of cold work and the annealing temperature, the cold finisher has a flexible setup by which he can get the physical properties needed on various items.

Softer cold heading steels will be in demand for more severe forming operations. Some very intricate parts are now being made by cold forming. Softer steels are available by improved annealing and less draft when cold drawing. Hot rolled steel, very close to round from the last pass, and better cleaning methods make light drafts possible.

The day of tailor-made steels is here. This is particularly true of cold finished products. Where there was previously one grade, there are now a dozen modifications, each different in some respect, in chemistry, physical properties, or grain size, and each for some definite application. It might be well to think of and appreciate the usefulness imparted by the cold finisher to his product. From hot rolled bars, covered with

scale, not very close to size, and with somewhat unpredictable physical properties, is made a product within one or two thousandths of an inch of the size intended, having a smooth bright finish, and physical properties as needed for some definite job. Such a product is beautiful by comparison. It is like a suit a tailor has made from his bolt of cloth. The cold finisher will undoubtedly continue to make desirable suits of various weaves and weights, and some with three pairs of pants!

Progress in Basic Openhearth

By W. J. Reagan
Assistant Superintendent of Openhearths
Edgewater Steel Co., Pittsburgh

IN ORDER to keep up with the tremendous advances made in rolling mill progress, it would appear that our principal steel making process, the basic openhearth, should soon be due for a rapid advance both in tonnage and quality.

That the increase in tonnage is an actuality can be noted in a recent report of one of the new furnaces, showing that a furnace of 135-tons capacity had in one month produced nearly 11,000 tons. This figure is a goal for many. In this particular case the tonnage seemed to be attained by a radical change in furnace design and also by the use of some of the newer bottom materials. It also, no doubt, was affected by other factors which have over a period of years contributed their share to rapid production. For example, sloping backwalls have certainly reduced delays and have become almost standard practice. The change to sloping backwalls has been gradual, but now its use in modern furnaces is almost universal in American plants.

Other factors that are in the process of evolution are temperature control devices (for roof temperatures, for bath temperatures, for regenerator temperatures), control of the reversing cycle, and last but not least control of the steel while it is being cast into ingot molds. Some of these have already shown considerable promise; during the next few years we should see many of their troubles eliminated. One particularly promising device is an instrument for measuring bath temperatures. By inserting a pipe into the steel bath, with a stream of low pressure air passing through it, temperature readings are obtained either with a radiation pyrometer or a photo-electric cell. In one melting shop a high speed recorder is used, eliminating largely the human element. The carbon-silicon-carbide thermocouple is an important device but is still having some of its kinks ironed out.

It goes without saying that any instrument that will measure steel temperatures accurately in the openhearth bath or on the pouring platform will provide the steel maker with a most valuable tool. When and if we have such an instrument, the probably revised picture of the physical chemistry of steel making will be of great interest.

Other factors in the process of evolution are slag control and deoxidation practice.

A variety of opinions are held as to the value and effect of slag control. Viscosity tests, pan-cake samples, chemical analyses, petrographic samples, powdered slags, all have their adherents and also their good and bad features. In a number of companies, one method of control is used in one shop, while in another shop another method is used with apparently just as good results. There is still considerable detail missing from the slag control picture, but the future seems to indicate that some of the data now in use will be dropped and other data now under way will be substituted. I personally believe the slag control problem to be much simpler than usually suspected.

Deoxidation practice is in about the same category as slag control. In one plant we find a certain type of deoxidizer used on a certain grade of steel with certain results being obtained. In another plant on a similar grade of steel we find another type of deoxidizer used, with apparently quite similar results. Both companies sell their product to the same consumer with, as far as can be determined, satisfactory results. The effect of the various deoxidizers upon the final product, and the proper method for their use during the deoxidation period, still is relatively unexplored, but possibly the future will have some answers to this important problem through some of the research work now under way.

Other problems of interest are furnace insulation and atmosphere control.

Furnace insulation below the floor level has become almost universal and there seems to be no question but that it has reduced costs materially. Above the floor level we have another problem, and possibly the future will

Method for Identification of Inclusions in Iron and Steel

Originated by Wm. Campbell and G. F. Comstock (Proc. A.S.T.M., Vol. 23, p. 521) and Modified by C. R. Wohrman, Merrill Scheil and Miss M. Baeyertz

Polish Specimen Carefully so as to Preserve Inclusions and Project Magnified Image on Ground Glass by Arc or Equally White Light Without Color Screen

Gray or Black Inclusions

Etch 10 sec. with 10% nitric acid in alcohol

Strongly Attacked LIME COMPOUND *from mold wash (rare)*

Unattacked Etch 5 min. with 10% chromic acid in water (Be careful to observe that the polished surface is wetted by the solution)

Weakly Attacked (slightly pitted or darkened) COMPOUND OXIDE: (a) either FeO with FeS in solution (usually accompanied by FeO-FeS EUTECTIC), or (b) FeO+MnO and other OXIDES in solution
Note 1: Octahedral crystals are probably MAGNETITE.
Note 2: Both (a) and (b) will be darkened further by 20 sec. sulphur printing (2% H_2SO_4 in water) and destroyed by etching with stannous chloride as indicated below

Attacked FeS-MnS, rich in MnS. Note: Reaction not always decisive. Any unattacked FeS-MnS will be blackened by next treatment

Completely Blackened
(1*) FeS-MnS, MnS below 50%
(2*) FeS-MnS, MnS above 50% or OXIDE very rich in MnO
* Refer to color before etch

Partly Attacked
(a) OXIDE rich in MnO (will be destroyed by stannous chloride)
(b) SILICATE with some MnO (will be destroyed by hydrofluoric acid)

Unattacked (or partly attacked in previous treatments) etch 10 min. with a saturated solution of stannous chloride in alcohol

Attacked IRON OXIDE or (if previously pitted) COMPOUND OXIDE

Unattacked (or previously pitted) etch 10 min. with 20% aqueous solution of hydrofluoric acid.

Attacked SILICATE (if previously pitted presence of Mn is indicated)

Unattacked Repolish and note color and form

If fine particles, very dark color, difficult to polish without pitting and not elongated by hot work is ALUMINA

If color not especially dark, easily polished smooth without pitting

Fairly large angular fragments, showing changeable bright spots as focus is changed, are SAND GRAINS (in steel castings)

Small angular particles, bluish in color probably TITANIUM OXIDE (in titanium treated steels)

Inclusions of Warm Colors

Etch 10 min. with boiling alkaline sodium picrate

Attacked IRON SULPHIDE (pale yellowish)

Unattacked

Etch 10 min. in 20% aqueous solution of HF

Attacked: Removes ZIRCONIUM NITRIDE (yellow cubes) and ZIRCONIUM SULPHIDE (tan crystals)

Unattacked Inclusions in high chromium steels

Etch 5 min. in boiling 10% H_2SO_4 + 1% $KMnO_4$, & lightly repolish*

Unattacked CHROMIUM OXIDE (purplish gray by reflected light, bright green by transmitted light)
TITANIUM NITRIDE (yellow cubes)
TITANIUM CYANO-NITRIDE (pinkish; strongly angular, easily pitted in polishing)

Attacked CHROMITE $Cr_2O_3 \cdot FeO$, isotropic; red to brown by transmitted light

Unattacked
Note color: (1) Very faint pale gray, (2) Medium or dark gray, and etch 5 min. with boiling alkaline sodium picrate

* Note: Suitable only for stainless steels with clean (unoxidized) surfaces.

Supplementary Tests

In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:

I Sulphur Printing

(for 20 sec. using a 2% aqueous solution of H_2SO_4)
(1) Dissolves all FeS-MnS inclusions
(2) Partly dissolves (pits) FeO containing FeS and OXIDES of other metals in solution
(3) Leaves unchanged: IRON SULPHIDE (pale yellow), pure IRON OXIDE (medium grey), SILICATES (dark grey)

II Matweieff's Tests

(a) Dilute tartaric acid does not attack OXIDES or SILICATES, but colors MnS lightly and FeS decidedly
(b) Heat sample in hydrogen at 1600°F., OXIDES are reduced, SILICATES and SULPHIDES are unaffected
(c) Repolish (b), etch with dilute $FeCl_3$ in alcohol; if reduced oxide particles are colored deeply they contain some Mn

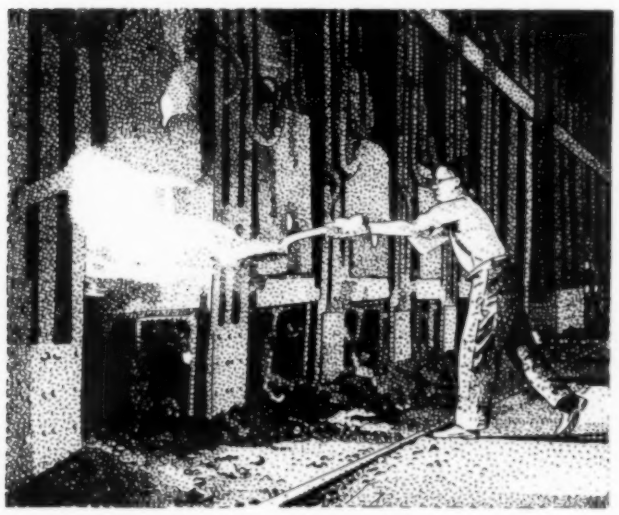
III Rohl's Test for Sulphides

Short etch with 1% picric acid in alcohol, then temper to dark yellow.
FeS turns dark blue to reddish violet, and MnS turns dull grey to bright white.

answer the question as to why at this point it is a success in some plants and an apparent failure in others.

Atmosphere control is a rather new idea. Apparently its greatest success has been in the furnaces built during the past few years. It also is in a process of evolution; notable advances have been made in its operation. Some of the modern control instruments developed for quite different purposes have helped materially, and here again the future should hold forth considerable promise.

All in all we should anticipate much valuable data from present research in the everlasting battle to reduce costs and to increase quality.



Refining Methods

By John Chipman
Department of Metallurgy
Massachusetts Institute of Technology
Cambridge, Mass.

ALONG THE ROCKY SHORE of one of those beautiful bays that indent the Maine coast, young son is busily hurling stones at an enemy battleship which has hove to some dozen yards off shore. The flimsy wooden box would be demolished by one direct hit of the ponderous projectiles, yet the cannonading has been going on for ten minutes and there she floats undamaged. The observer on the hill notes that some stones are falling two yards short; others are equally over. "Use smaller stones," he suggests, "and all about the same size; you'll do better." The operating department adopts the suggestion and sure enough he is doing better. He almost hits it. Practically all of the stones now fall within a one-yard radius. "Take your time," from the observer; "aim more carefully," and with this encouragement the enemy fleet sustains a grazing blow which inflicts no damage whatever.

A few more salvos from the shore battery. No hits. The observer fidgets from his hill, picks up a stone. "Trouble is," he remarks, "your probable error is too great. Your range and direction are O.K. and your average is good, but you need practice to decrease your mean deviation." Observer's first shots go wild. "Getting the range," he explains. Five minutes later the enemy, still untouched, is drifting seaward. "Let's stop for lunch," says the observer.

Did you ever look through a file of openhearth records to select one heat which would be average and normal and typical of the practice? Sometimes we doubt that such a heat can be made. Instead we average the recorded figures and find, for example, that our practice involves the use of 9.28% limestone and 33.02% hot metal containing 1.07% silicon and 0.029% sulphur, and charged at 2583°; that the average slag contains 21.25% FeO, the average observer recorded 2940° as the tapping temperature, and the average analysis was exactly where the metallurgist wanted it.

Try and find one heat that agrees with this average in any two items excepting observed tapping temperature! And there are a score of other variables recorded on any good openhearth heat record. Of what earthly use is an average heat if it is non-existent? It's like the average shot that would have sunk the ship if it had occurred. The average is without significance unless the overall range or mean deviation is also known. Even if an average heat is non-existent, a mean deviation is something very real and practical — a numerical thing which, like costs or fuel per ton, can be diminished only by hard work.

In the metallurgist's Utopia the steel in every heat of given grade will be exactly alike in all its properties. Its response to heat treatment, machining, deep drawing, upsetting, surface hardening, aging or what have you, will always be the same. There will be no variation from the normal behavior — and no rejections. In the same Utopia the openhearth operator must be supplied with absolutely uniform materials and with Utopian refractories, and no one must ever tell him at ten o'clock that the mild steel heat in No. 5, scheduled to tap at 11:30,

must be diverted to chrome-vanadium spring stock with close carbon limits.

Granting that Utopias are unattainable and admitting a doubt that their attainment is desirable, how can we work in the general direction of greater metallurgical uniformity when at the same time our raw materials are becoming more diverse and when demands for extreme specialization are placing a constantly growing burden upon all steel makers?

If I read the signs of the times correctly, progress in this direction will be made along two important lines which are already under way in many steel mills.

The first of these is in the training of personnel — not only technical training, important as that is, but also the development of an attitude of responsibility and teamwork throughout the organization. Many steel mills are fortunate in their background of long cooperation between management and workers. In others progress along this line will be slow.

The second line of progress is in research on the basic principles underlying steel making methods and in making available to the steel maker new information, new aids in the control of his process, new kinds of equipment which will enable him to do a better job. The past five years have witnessed notable progress along this line. The almost universal acceptance of some kind of slag control has led to the introduction of various methods for judging the properties of slag. The development of accurate methods for oxygen determination as well as the introduction of rapid analytical methods in the control of this element have completely knocked the mystery out of that old ghost, oxidation of the bath. Application of the photoelectric cell to control the bessemer converter is making its product more uniform, heat to heat. Several devices for the accurate determination of bath temperatures are being used and although we would not hazard a guess as to which will come into general use, it seems probable that within the not distant future steel makers who wish to determine and control bath temperatures will do so. No other single development has such potentialities in controlling the uniformity of the product.

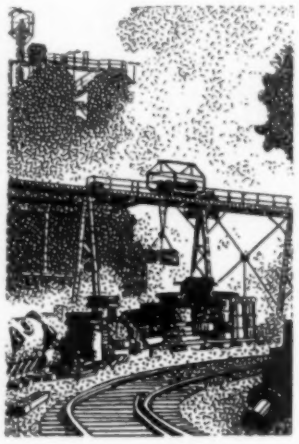
The practical approach to the control of uniformity of product must be based upon adequate statistical information regarding the product itself and the variables of its manufacture. To this end more or less elaborate statistical systems are being employed in which complete records of openhearth variables may be correlated with the several factors of quality and uniformity. With the aid of modern card-punching, sorting and tabulating equipment, it becomes possible to handle records of an almost unlimited number of heats. With such a system a metallurgist with a knowledge of statistical methods (perhaps assisted by a statistician with a smattering of metallurgy) is in position to guide the metallurgical practices in his plant not only into a narrower groove of smaller deviations, but also in the direction of lower rejections and higher quality.

Bessemer Steel

By H. W. Graham
Director of Metallurgy and Research
Jones & Laughlin Steel Corp.

AN ITEM of metallurgical interest in the history of the past year is the widespread and renewed attention to Bessemer's process for steel making. For years bessemer production has been dwindling and the product has been under a cloud, made up of more-or-less equal parts of ignorance and misinformation. Recently the metallurgists who really know the process have become vocal in protesting that the method (and the equipment for its operation) is too valuable to abandon.

With support from the manufacturing departments, and from management generally, metallurgists are turning their attention to "the forgotten man" among steel making processes. With experience gained in extensive openhearth work, with the excellent instruments available today, and with a generally high level of metallurgical knowledge, technological progress in bessemer operation was bound to be rapid. There lacked only the interest and the will to do, and both of these elements are now being supplied.



Bessemer steel making has been found to be a fertile field for experimentation, with good returns in improvements for relatively modest expenditures in

money and man-power. It has already been found that the technological problems are really quite simple and that solutions of practicable character can be achieved.

At least one plant is regularly and successfully de-phosphorizing. Another is de-sulphurizing. A third is reported to be organizing for application of the Perrin process. Still another plant reports that it has achieved instrumental control of the end point of the blow to supplement or replace the blower's judgment.

Control of temperature during the blow is now better understood and more successfully applied. As to controlling the degree of oxidation, it is understood that openhearth methods of slag control cannot be applied, since it is impracticable to obtain samples of either slag or steel during the finishing period and since the rapid reactions do not allow time for the examination or analysis of such samples, even if they could be obtained. Nevertheless it is being demonstrated that the degree of oxidation existing can be set to pre-determined close limits and reproduced from blow to blow with excellent results. Therefore the very restrictions of bessemer operation produce a condition of simplicity that does not exist in the openhearth.

Recent advances of importance have been made in understanding the conditions which affect the absorption of nitrogen, and the day seems close at hand when a really effective control of this element will have been achieved. This situation will have a far reaching influence on the duplex process, in which bessemer practice plays such a vital part.

It is significant that this renewed interest by metallurgists, operators, and commercial people is not confined to the United States alone. It is world-wide in scope. England is again becoming a producer of bessemer steel, production on the Continent is sustained and increasing, India has made important changes in its uses of convertor facilities, and a duplex plant is being built in Japan.

This change of attitude will produce a new growth of technical literature on a neglected steel making method. In the past year there has appeared a worthwhile paper on English acid convertor practice, and more may be expected here and abroad. The Bessemer Committee of the American Institute of Mining and Metallurgical Engineers is being reorganized, parallel to its Openhearth Committee.

Everywhere one hears "The bessemer process is coming back!" Evaluation of this statement points to two factors—quality and tonnage. It appears certain that control methods are rapidly bringing bessemer steel to a uniformity and high level which will give it fully satisfactory workability in numerous fields of application. From that point on the tonnage produced will depend upon economic considerations; just how they will work out cannot now be predicted with accuracy. In any event, the production of bessemer steel is now a field of live interest to the metallurgist.

Developments in the Pouring Pit

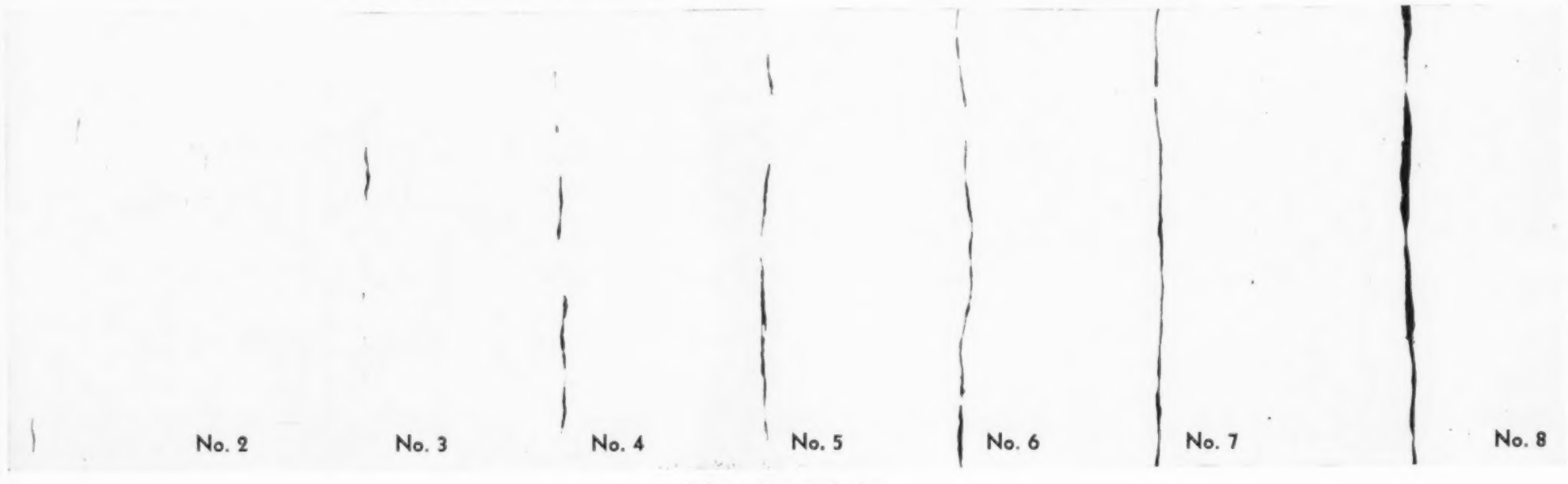
By Gilbert Soler
Manager of Research, Steel & Tube Division
Timken Roller Bearing Co.
Canton, Ohio

THE IMPORTANCE of the pouring pit operation has been recognized by plant managers, for the quality of steel as tapped from the furnace may be jeopardized by poor or inefficient work at that point. Improvements in pouring pit technique have resulted, and special attention has been given to the training and morale of the personnel. Standardization of practice with constant vigilance on the part of the supervision has resulted in improved quality and lowered costs. The advances in making the pouring pit a safe place to work have been noteworthy.

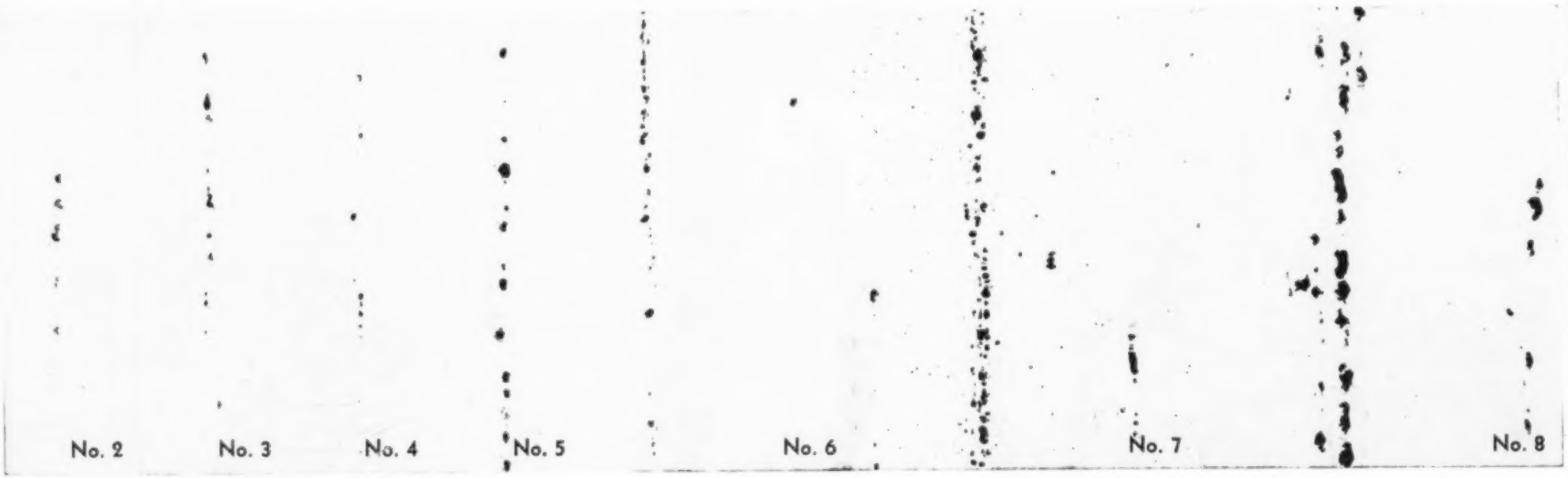
Mechanical handling equipment has been developed to a high degree of efficiency and

Rating of Inclusions ("Dirt Chart")

In use by Chevrolet Motor Co. *Developed by George W. Walker*



Silicate Slag Inclusions



Oxide Inclusions

safety. Welded ladles, oval-shaped ladles for greater capacity, multiple pouring, smoother operating buggies, and better cranes are recent developments.

Refractory materials of construction have had only slight improvements. Recently attention has been given to the development of better nozzle brick designed for the purpose intended — that is, as a pouring orifice for steel. The recent symposium on "Pouring Pit Refractories", held jointly by refractories manufacturers and openhearth operators, evidences the interest in this subject. Considerable development has been made in Europe and Britain, especially in nozzle brick. The use of basic ladle linings has been tried with fair success in this country, although a brick especially designed for the purpose has not been developed. It is encouraging to note that refractory manufacturers are taking a decided interest in improving pouring pit materials.

Mold material has not been improved to any great extent, although mold design has received a great deal of emphasis, and more attention is given to the selection of the proper type of molds for specific types of steel.

Cost considerations have increased the use of larger molds over the past ten years, since mold life per ton of steel is increased and less units need be handled, thus reducing labor costs and increasing the capacity with existing equipment. On the other hand, several small electric furnace plants now pour small ingots and roll direct to finished size, thus saving a rolling conversion cost, when surface requirements of the product are not rigid.

Materials for coating molds have not been improved; tar, graphite, rosin, aluminum washes, and lacquer mixtures are still used.

Fireclay hot tops have not been changed in general design and only a few minor features have been added during the past ten years. Permanent hot tops have come into use during this period and are now being used for some types of steel. Of recent years attention has been given to hot top coverings of an insulating or exothermic nature to lessen segregation and reduce piping. Their use is not at all general, however.

The use of bottom pouring or rimming steels has increased, due to more stringent requirements by continuous strip mills as to surface of the slabs. Many killed steels are bottom poured for plate and forging grades.

During the past few years attempts have been made on a commercial scale to cast steel direct from the furnace into the rolling mill line in a continuous process for the production of bars or strip. The aim has been to reduce cost rather than improve internal quality. Attempts were made in 1931 to centrifugally cast steel into blooms. Centrifugally cast steel gears for automotive use have been a recent development. The growth of the steel casting industry indicates many possibilities of cost reduction.

Fundamental information on the effect of mold design, pouring technique, and ingot solidification is needed if internal structure and exterior surface are to be improved. Considerable work has been done. Improvements must also be made in materials and equipment used in the pouring pit.

Low Alloy Steel Castings

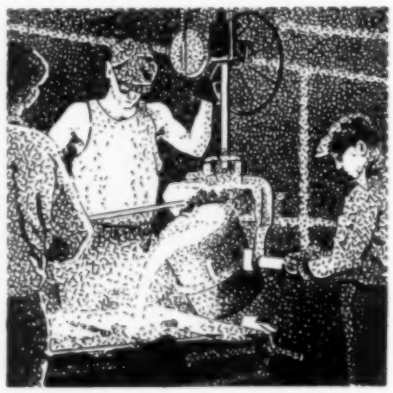
By C. E. Sims
Battelle Memorial Institute, Columbus, Ohio

DEVELOPMENT of low alloy steel castings has been rapid in the last few years and research now under way is expected to solve some of the remaining problems. This work follows three main lines of endeavor, namely, the selection of the proper composition and heat treatment of the metal, the improvement of foundry technique, and better design.

As regards composition, some 75 to 100 combinations of the half dozen available alloying materials have been proposed and used at some time or other. It is quite doubtful if there are that many necessary variations in physical properties, and the current tendency is to reduce greatly this number, relying on those analyses that have proven more practicable.

Manganese continues to hold the lead as the most popular hardening and strengthening alloy. In the normalized steels where a grain refiner is also needed, vanadium or titanium is generally added. For castings in which high hardness is not demanded, heat treatment

by normalizing holds precedence over liquid quenching, because it is a simpler process and gives less trouble from warping. For such castings, compositions have been developed to give the optimum combination of properties in the normalized state. When the heat treatment includes a quench and draw, molybdenum is a favored alloy complement of manganese.



In the design of low alloy steel castings there are two different trends. The first does not contemplate weight saving primarily but works in the direction of giving more rugged structures with a greater margin of safety. This introduces no particular problems in design but does result in an indirect weight saving by increasing the capacity of the part.

The other trend is to lighten the weight of existing structures without any sacrifice in strength. This can only be done by lightening sections and such a procedure introduces many problems in design and casting technique. Because the stiffness or rigidity of a steel structure is a function of section modulus and not of the strength of the steel, the difficulty of designing light structures for adequate rigidity becomes acute. So far a great deal of ingenuity has been shown. Although there is much in common in the design problems of light weight alloy steel castings and light weight alloy wrought steel structures, there is an advantage with the former in the facility with which sections can be tapered and weight can be shifted to the positions where it will do most good. In many structures the specifications have been changed to allow greater maximum deflections under load, because of the higher yield strengths of the alloy steels.

The difficulties of obtaining perfect castings are also greatly increased as the section is reduced. If the steel is poured too cold, misrun castings or cold shuts are obtained, and if too hot such troubles as cutting, spalling and burning-in of the sand result in surface defects. As the section is decreased, moreover, various surface defects, core shifts and other irregularities seem to assume an importance more than proportionate to their percentage of the cross section. In other words, higher grade castings are required for lighter designs.

It can be said to the credit of foundrymen that they have fully recognized these problems and are assiduously attacking them. They have themselves set high standards of perfection for the light weight castings. A great deal of work is being done both here and abroad on the study of fluidity or castability of steel. Important fundamental studies of molding sands are being conducted in various laboratories.

In all this work there has been shown a great willingness to work for the common good. There is an apparent readiness to compare notes, and groups of foundries are collaborating to pool their information or to finance rather ambitious joint research programs.

One factor which should not be underestimated in its contribution to the success of the low alloy steel casting is the growing recognition that castings are not necessarily, as was so widely believed in the past, a second-best substitute for a wrought steel structure. Castings have engineering values in their own right and in many uses, as for instance where flow lines lead to failure, the lack of directional properties in castings makes them more enduring than forgings. The best example of this is the substitution of cast steel gears for forged gears for automotive uses. Moreover, steel castings lend themselves as readily to various heat treatments as wrought steels. The old fear of damaging castings by liquid quenching is not tenable for modern products of the foundry. This is due primarily to the balanced compositions in use, but is contributed to by improved mechanical integrity.

Gray Iron Castings

By A. C. Denison
President, Fulton Foundry & Machine Co.
Cleveland, Ohio

GRAY IRON FOUNDRIES have made tremendous advances in the technique of gray iron manufacture in recent years, an advance so definite that today engineers are using basic figures for design in gray iron far above those considered safe some years ago. Further than this, there is a general acceptance of modern higher strength gray iron products based on specification purchases that registers confidence

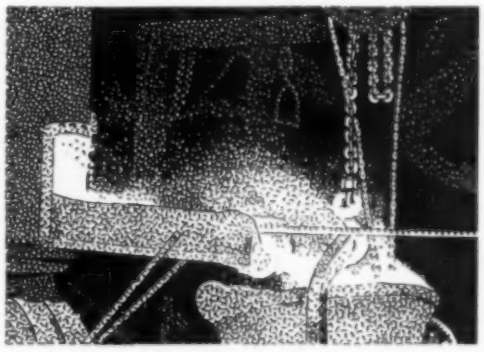
in these higher strength irons as a dependable development.

This development of better standards is leading to a new day in the gray iron foundry business. The purchasers and engineers are thinking of iron in terms of specifications. Irons with definite physical characteristics are now specified to A.S.T.M. Standards by progressive users, rather than to designate purchases by the general term *"cast iron"*, which may mean anything. Furthermore, gray iron foundries are quite generally now organized to manufacture good irons to A.S.T.M. specifications, rather than to just produce something that could be called cast iron.

This change in product has come from metallurgical research by the foundries themselves and from the research carried on by venders of alloys and other foundry raw materials that have become generally helpful.

These changes and developments in foundry products now accepted so generally are indicative of what is ahead for gray iron in the future. Those familiar with research trends know that greater advances are coming, so that gray iron will be graded for many special services, such as wear resistance to different abrasives, heat resistance in certain ranges of temperature, corrosion resistance to definite surroundings, and specific electrical properties, as well as for general mechanical properties.

This leads modern foundries to manufacture a group of products with many properties obtained by alloying and various process manipulations, and as one visualizes the future two developments are in progress that will lead to new accomplishments:



(a) New combinations of alloys will improve specific properties of gray iron for special applications.

(b) Heat treating of gray iron will be expanded to create new and better properties. This thought involves not only quenching from temperatures above the critical followed by various drawing temperatures, but also heat treatments at temperatures below the critical (which recent research has shown to have possibilities worthy of important consideration).

Thus gray iron now is taking a new place as an engineering material because the newer products not only have the important properties of vibration damping, high compression, and low friction characteristic of the old gray irons, but also have superior strength and other physicals that place the material close to the other strong metals.

Malleable Iron

By Harry A. Schwartz
Manager of Research
National Malleable & Steel Castings Co.
Cleveland, Ohio

SINCE MALLEABLE IRON, properly so called, meaning the ferritic material, has been known for over 120 years and intensively studied by a number of competent metallurgists for 25 or 30 years, it is unlikely that anything very new in principle bearing on its manufacture and use will be discovered in the near future.

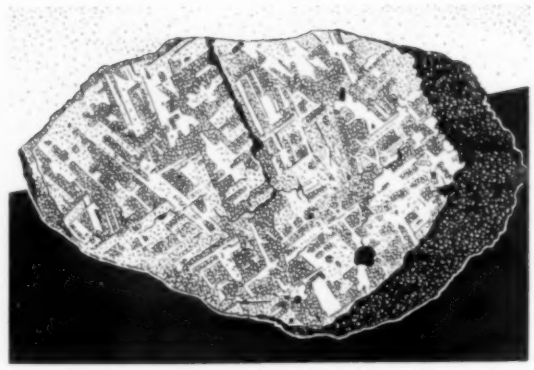
The only thing which might be done to change the properties of such material would be the addition of copper, with or without subsequent precipitation hardening; this process has been thoroughly explored and awaits only a commercial demand to be put into execution.

It is the writer's opinion that the dramatic question of reducing annealing time is rapidly approaching the stage where it will be viewed from its economic aspects rather than as a means of attracting attention to the fact that the art is being intensively studied. Since quick annealing is accomplished either by taking advantage of entirely well known metallurgical principles as to the use of accelerators, or more commonly by improvements in furnace design, there comes a point at which the increased cost of highly specialized furnaces, very carefully supervised melting operations requisite to maintain uniformity of annealability, and occasionally special raw materials, outweigh any possible saving to be had by the reduction of heat treating time. The trade is apparently wisely realizing that it wants a material of adequate properties in a reasonable time, but not in the shortest possible time at an increased expense or risk.

New combinations of properties are more likely to be found in the various so-called "pearlitic malleables". Materials of this type can be made covering a rather wide range of properties. Various manufacturers have developed various techniques and materials to suit specific purposes.

There is a considerable cry for standardization as to these materials; the cry, however, seems to emanate not so much from users of the material as from independent engineers. The writer believes and certainly hopes that this standardization will not proceed too rapidly. Until it can be shown that all the very diverse requirements of the enormous number of consumers in the United States can be met by a few standardized products, it would certainly be an injustice to eliminate from the market useful metallurgical products now being manufactured to the satisfaction of both the consumer and the producer.

A further complication is the fact that a great number of pearlitic malleables are covered by patents and that any premature standardizing might result in giving a virtual monopoly to some producers when other competitive materials do in fact exist but would be barred from the market by the artificial barrier of the creation of standards. The only possible solution would seem to be that adopted last June by the A.S.T.M. — a classification of properties without excluding any combination of them which may have commercial utility.



Alloy Cast Irons

By Garnet P. Phillips
Foundry Metallurgist
International Harvester Co., Chicago

USE OF ALLOY cast irons continues, with emphasis on applications where the properties obtained with alloys are entirely justified from economic and operating viewpoints.

The user demands them for higher physical properties, increased heat and corrosion resistance, greater wear resistance, for heat treatment and for specific thermal expansion characteristics. The foundryman uses alloys (in addition to the above reasons) to produce special castings with properties that cannot be met with the one or two base irons regularly available in his foundry.

The alloys nickel, chromium, and molybdenum, alone and in various combinations, have been used in large quantities in cast iron for some years. Copper, vanadium and titanium have been used in lesser quantities. More recently copper is being used in increasing quantities but, notably, not at the expense of other alloying elements. It is finding increasing use in many applications where the utilization of more costly alloys is not warranted.

Research continues for the best and most economical alloy combination for each specific application. The full effects of various alloy combinations on all the usual physical properties have not yet been explored by any means. Our knowledge of alloying effects on thermal expansion and heat conductivity is in many cases woefully lacking. More complete control of graphite particles, their form and distribution, by means of alloys offers a fertile field for research, since this means better control of physical properties.

Alloy irons with higher heat conductivity and resistance to local thermal gradients have a wide field of usefulness awaiting them. Irons suitable for heat treatment (either the conventional quench and draw or surface hardening) that can be produced more economically than those now normally used will open new fields of application.

Ferro-alloys containing carbide-forming elements along with economical graphitizers have been formulated and now are being tried; they may find wide application.

Hot quenching of suitable alloy irons in thinner sectioned castings is one of the newer developments in heat treatment that may find many uses.

The use of alloys in cast iron will probably increase in specific fields of application where special or unusual properties are needed. Research will widen the fields of application on the broad base already attained.

FORGING AND FORGING MACHINERY

METAL PROGRESS
OCTOBER 1939

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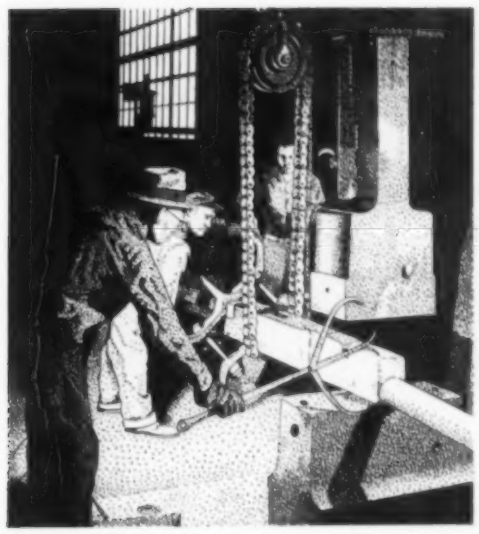


Forgings and Forging Machinery

Boom in Drop Forging

By R. W. Thompson
Sales Engineer, Transue & Williams Steel Forging Corp.
Alliance, Ohio

DIVERSIFICATION of drop forging applications has continued during the past year. Manufacturers, realizing the value of lighter construction, have been quick to adopt drop forgings for economical operation of their equipment.

Mechanization of farm tools and agricultural equipment has already provided a large field for forgings. With the recent trend to streamlined designs in farm tractors, accompanied by greater operating efficiencies and more attractive models, an increasing market is apparent and it will continue for several years to come.

The ability of the drop forging industry to fabricate the unusual shapes presented them with success is a result of the experience largely gained in the mass production of the many intricate automotive designs. These designs, engineered so as to provide the greatest strength and safety in transportation, are tributes to the forger's ingenuity and forgings' perfection.

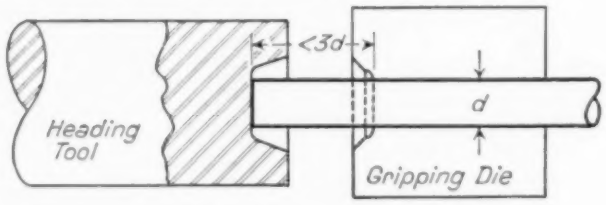
In the very recent past there has been a decided change in the drop forging industry in respect to the individual company's interest in the allotment of specialized forging parts. With business conditions wherein many shops are operating nearly to capacity, forging companies are being more mindful of the parts for which their particular equipment is adaptable. Heretofore many contracts were earnestly solicited and the business secured whether it could be readily made or not. Frequently the operations were conducted by makeshift arrangements which would not permit a quality job, to say nothing of the impossibility of a manufacturing profit. With the expected prevalence of sufficient business to keep operations at near capacity limits, it is believed that competitive companies will seek those jobs within their own scope and range of manufacture; better profits will therefore be realized and higher grade and more satisfactory products assured to the customer.

The future looks exceedingly bright. The magnitude of the potential business in aircraft forgings can hardly be forecast, as the develop-

Rules Governing Forging Machine Dies

(Adapted from E. R. Frost; Courtesy National Machinery Co.)

Rule I— The limiting length of unsupported stock that can be gathered or upset in one blow without injurious buckling is three diameters.

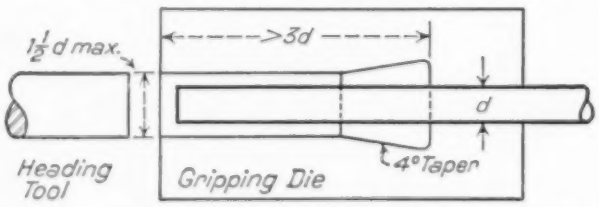


Note. (*a*): A safer maximum length is $2\frac{1}{2}d$; little attention need be paid to squareness of end if $l=2d$. If $l>3d$, buckling will occur near the middle of the unsupported length. These principles hold irrespective of whether the stock overhangs the face of the gripping dies, or whether any portion is gathered in either gripping dies, heading tool or both.

Rule II— Lengths of stock more than $3d$ can be gathered or upset in one blow provided the upset is contained in either the gripping die or a straight or slightly tapered hole in the heading tool, and the diameter of the upset made in that blow is not more than $1\frac{1}{2}d$.

Note (*a*): Multiple buckling will be checked by contact with sides of the die, and friction therewith will cause a fin to form around end of upset. Such long upsets cannot be made half in one die and half in the other, for central buckle will receive no side support.

Note (*b*): A safer maximum is $1.3d$, and if Rule I is also applied, the upset will be free from end fins.



Note (*c*): For very long upsets, it is helpful to have the end of the bar at a lower temperature, and to have a minimum diameter upset for the outer half of the die, the inner half tapering 4° to wider diameter at the base.

Note (*d*): In upsetting tubing, wall thickness cannot be increased externally more than 25% at one blow; internal upsets are almost unlimited because arch effect prevents internal buckling.

Rule III— For upsets requiring more than $3d$ in length of stock, and in which the upset is $1\frac{1}{2}d$, the amount of unsupported stock beyond the face of the die must not exceed $1d$ (operation 1, at right).

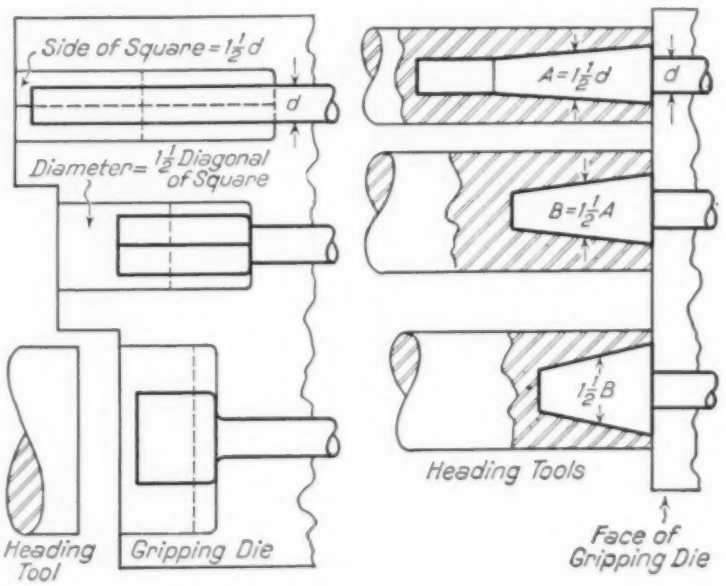
Note (*a*): Unsupported stock can amount to $1\frac{1}{2}d$ if diameter of upset is reduced to $1\frac{1}{4}d$.

Rule IV— Large amounts of stock can be gathered by multiple application of Rule II and III, and by using square or tapered impressions.

Note (*a*): In making the wide flange in sketch at left, below, the first and second impressions are within the $1\frac{1}{2}d$ limit, but the third, being a short upset under Rule I, is unlimited in diameter.

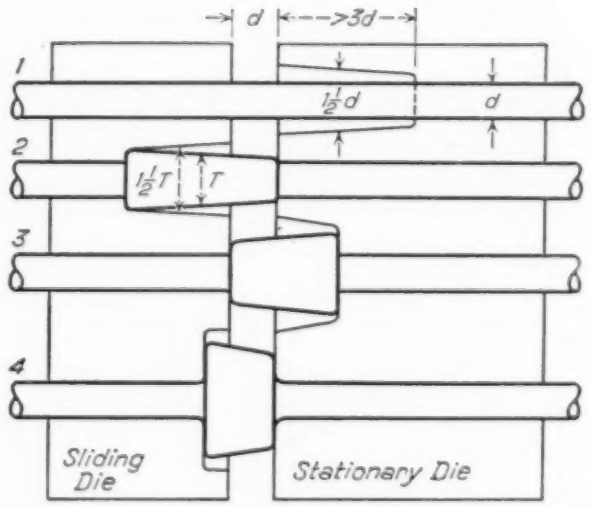
Note (*b*): The side of the square may be $1\frac{1}{2}d$ of the original bar, and the diameter of the next round may be $1\frac{1}{2}$ times the diagonal of the square.

Note (*c*): Tapered holes are proportioned as to their diameters at midlength of unsupported stock.



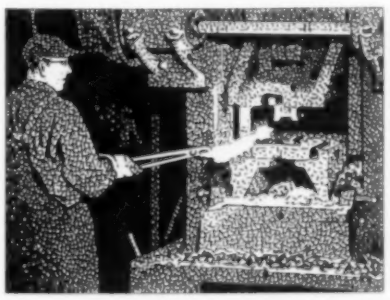
Rule V— Sliding dies, for upsetting stock at some distance from the end of a bar, are governed by all the above rules.

Note (*a*): Friction along the sides of the sliding die will favor upsetting near its front end, so multiple impressions should be alternately in front and rear half, or alternately in sliding die and gripping die, as shown in sketch below.



ment of this phase of transportation apparently is unbounded. There are already several planes on the market which can be purchased at little more than a fine automobile.

The vast expenditures of the Government in a larger program for preparedness contain an allocated portion to be spent on equipment requiring drop forgings ranging from a fraction of a pound up to those of over a thousand pounds in weight. Specifications for these parts present no particular hardship to the forger, as the various tests for quality are a part of routine procedure for which proper control has long been established.



New forging designs have come from bus and motor coach builders, made necessary by changing the location of engines from front to rear. This change in coach construction has shown such advantages that it is believed it will be adopted quite generally in automotive design within the next few years.

Predicated on the present business uptrend, there is little doubt but that the next year or so will see a volume of business in the drop forging industry which will equal and possibly exceed any similar period in the past.

Pressing and Forging Machinery

By Ernest E. Thum
Editor, Metal Progress

ASIDE from a continued refinement in detail of all classes of metal working machinery, the last year observed a definite trend in three directions. First is the appearance of numerous self-contained units. Second is the development of specialized equipment for pressing or cold forging aluminum alloys. Third is the continued growth of steam hammers in weight and size.

Large hydraulic presses have long been built as complete units — that is, having pumps and oil reservoirs resting on the upper crosshead. Last year a number of smaller presses, ranging from 5 to 50 tons, have followed this style and have appeared on the market, smoothly encased in steel cabinets. Electrically operated, air driven hammers, each a complete unit, are also available ranging in size up to those with 2000-lb. rams.

Multiple production of aircraft to single designs has, of course, required the production of great numbers of peculiarly shaped forms out of duralumin sheet. Fortunately, the dies can be made of hard wood or fusible alloy, and many rope drop hammers are slamming out the parts. Their advantage, other than rapid change of dies, is that the work is gradually done without friction clamping at the edges, and the raw material is gathered into shape with increasing wall thicknesses, rather than being stretched into thinner walls. Air-operated drop hammers to do this work have appeared, having ready control of the height of drop (one major convenience of the rope drop hammer), and with accurate slides and guides. Such equipment has much to recommend it to jobbers of parts in other metals, plagued with short runs.

Very large hydraulic presses — large in respect to clearance between columns — are also used with a rubber mass for the upper die. This process was devised by Henry E. Guerin of Douglas Aircraft Co., and described in METAL PROGRESS for May 1938. Numerous dies may be arranged on the bed of such a press, and on each laid a blank of duralumin sheet. One stroke of the press then forms as many pieces as can be assembled on the bed. This may be 30 to 35, so presses may have four lower carriages on tracks coming away at right angles, the carriages being loaded or unloaded while the third is being squeezed. Another interesting mass production device is a turntable, centered on one column, which carries brass blanks successively under pre-form, indent and heading operations to make 6-in. cartridges in a single 2800-ton press.

Steam hammers continue to grow in size. In last year's issue a 35,000-lb. hammer was noted as our largest in America. Another of the same nominal rating, but having an actual reciprocating weight including a 10,000-lb. top die of 52,000 lb., has been made; it can handle dies up to 44x90 in. Additional hammers of 50,000-lb. capacity are under order for foreign delivery. These huge hammers are primarily for large drop forgings in aluminum alloys, which are not so plastic at their mild working temperature as most of the alloy steels at white heat.

Standard Tolerances for Forgings up to 100 Lb.

Summary of Standards Adopted by Drop Forging Association, 1937

TOLERANCES, within the scope of these standards, shall be either "special" or "regular."

Special tolerances are those particularly noted on the drawings or in the specifications, and apply only to the particular dimension or thing noted. They may state any or all tolerances in any way as occasion may require. Regular tolerances apply in all other cases.

Regular tolerances in general forging practice are known as (*a*) "commercial standard," for general forging practice, or (*b*) if extra close work is desired involving additional expense and care in the production of forgings, "close standard" may be specified.

Class I—Thickness Tolerances

For drop hammer forgings, thickness tolerances shall apply to the overall thickness measured in a direction perpendicular to the fundamental parting plane of the dies.

For upset forgings, thickness tolerances shall apply to the metal actually enclosed and formed by the dies, measured parallel to the direction of travel of the ram.

Thickness Tolerances in Inches

Max. Net Weight	Commercial		Close	
	Minus	Plus	Minus	Plus
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.111	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Class II—Width and Length Tolerances

Width and length tolerances shall be alike, and are classified in three subdivisions (*a*) shrinkage and die wear tolerance, (*b*) mismatching tolerance, (*c*) trimmed size tolerance.

For drop hammer forgings, width and length tolerances shall apply to the metal actually enclosed and formed by the die, as measured parallel to the fundamental parting plane of the dies.

For upset forgings, width and length tolerances shall apply to directions perpendicular to the direction of travel of the ram.

II(a)—Shrinkage and Die Wear Tolerances

See table below. These shall not be applied separately, but only as the sum of the two; they shall be measured in such a way as to eliminate draft or variation in draft. They apply to that part of the forging formed by a single die block, and to no dimension crossing the parting plane.

Shrinkage and Die Wear in Inches

Length or Width	Shrinkage		Max. Net Weight	Die Wear	
	Commercial + or −	Close + or −		Commercial + or −	Close + or −
1 in.	0.003	0.002	1 lb.	0.032	0.016
2 in.	0.006	0.003	3 lb.	0.035	0.018
3 in.	0.009	0.005	5 lb.	0.038	0.019
4 in.	0.012	0.006	7 lb.	0.041	0.021
5 in.	0.015	0.008	9 lb.	0.044	0.022
6 in.	0.018	0.009	11 lb.	0.047	0.024
For each additional inch add	0.003	0.0015	For each additional 2 lb. add	0.003	0.0015
For example:			For example:		
7 in.	0.021	0.011	13 lb.	0.050	0.026
12 in.	0.036	0.018	21 lb.	0.062	0.031
18 in.	0.054	0.027	31 lb.	0.077	0.039
24 in.	0.072	0.036	41 lb.	0.092	0.046
36 in.	0.108	0.054	51 lb.	0.107	0.054
48 in.	0.144	0.072	71 lb.	0.137	0.069
60 in.	0.180	0.090	91 lb.	0.167	0.084

II(b)—Mismatching Tolerance

Mismatching is the displacement of a point in that part of a forging formed by one die block of a pair, from its desired position when located from the part of the forging formed in the other die block of the pair, measured in a projection parallel to the fundamental parting plane of the dies. It does not include any displacement caused by variation in thickness of the forging; mismatching tolerances are independent of and in addition to any others.

Mismatching Tolerance in Inches

Max. Net Weight	Commercial	Close
1 lb.	0.015	0.010
7 lb.	0.018	0.012
13 lb.	0.021	0.014
19 lb.	0.024	0.016
For additional 6 lb. add	0.003	0.002
For example:		
37 lb.	0.033	0.022
55 lb.	0.042	0.028
79 lb.	0.054	0.036
97 lb.	0.063	0.042

II(c)—Trimmed Size Tolerances

The trimmed size shall not be greater nor less than the limiting sizes at the parting plane imposed by the sum of the draft angle tolerances and the shrinkage and die wear tolerances.

Class III—Draft Angle Tolerances in Degrees

	Drop Forgings		Upset Forgings	
	Outside	Inside Holes	Outside	Inside Holes
Nominal angle	7	7 or 10	3	5
Commercial limits	0 to 10	0 to 13	0 to 5	0 to 8
Close limits	0 to 8	0 to 8	0 to 4	0 to 7

Class IV—Quantity Tolerances

Any quantity shipped within the quoted limits of over-run or under-run shall be considered as completing each release or part shipment of an order. Limits are as follows:

Quantity Tolerances

Number on Order	Over-run	Under-run
1 to 2	1 piece	0
3 to 5	2 pieces	1 piece
6 to 19	3 pieces	1 piece
20 to 29	4 pieces	2 pieces
30 to 39	5 pieces	2 pieces
40 to 49	6 pieces	3 pieces
50 to 59	7 pieces	3 pieces
60 to 69	8 pieces	4 pieces
70 to 79	9 pieces	4 pieces
80 to 99	10 pieces	5 pieces
100 to 199	10%	5.0%
200 to 299	9%	4.5%
300 to 599	8%	4.0%
600 to 1,249	7%	3.5%
1,250 to 2,999	6%	3.0%
3,000 to 9,999	5%	2.5%
10,000 to 39,999	4%	2.0%
40,000 to 299,999	3%	1.5%
300,000+	2%	1.0%

Class V—Fillet and Corner Tolerances

Fillet and corner tolerances apply to all intersecting surfaces even though drawings or models indicate sharp corners. If such drawings or models have or indicate (even though actual dimensions are not specified) fillet or corner dimensions of larger radii than the following standards, such larger dimensions shall be considered as actually specified and the tolerances shall be "special tolerances."

Where a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase toward the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

Fillet and Corner Tolerances

Max. Net Weight	Commercial	Close
0.3 lb.	3/32	3/64
1 lb.	1/8	1/16
3 lb.	5/32	5/64
10 lb.	3/16	3/32
30 lb.	7/32	7/64
100 lb.	1/4	1/8

Fuels, Heat Control and Instrumentation

By Adam M. Steever
Superintendent, Columbia Tool Steel Co.
Chicago Heights, Ill.

PAST HEATING TROUBLES have become history. Improved techniques which fully meet today's needs are with us or at least available without mystery or confusion to those that need and want them. Those that plan ahead are at the moment thinking in terms of expanded output to meet war needs or at least a sharp increase in business activity and the problems that lie ahead.

Open and semi-muffle furnaces, especially those operating with improved gas and oil burners and air supplied by blowers and also some of the coal furnaces fired with stokers and blowers, are economically filling the needs of the day. Temperatures, atmospheres and heating rates are being produced that give the maximum overall economy. It would appear that these methods are not to be quickly discarded in the immediate future. Only radical changes in the value of products or the cost of man-controlled manipulations will disturb the economy of our present methods. The tendency towards the increased use of the more easily and accurately controlled gas for fuel may be expected to continue and, no doubt, we can expect further improvement in the handling of other fuels aimed at meeting this competition.

The full muffle furnace, retort or electrically heated furnace with prepared gas atmosphere is well developed in principle but up to now has not justified its cost except for use in heating and treating finished products or quite valuable material in the raw or semi-finished state. One of the problems of this type of heating is the difficulty in making gases which are in equilibrium with the hot metal products, and the high degree of purity and accurate control necessary to maintain the desired conditions.

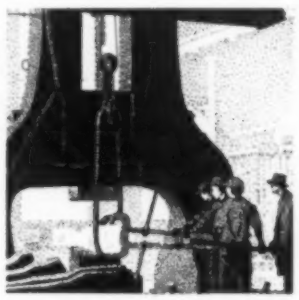
Undoubtedly, we have ahead of us many applications for the new nitrogen generator and the charcoal gas apparatus and we have reason to expect that new uses for these will be found in the near future. The units for producing non-scaling gas have already received wide application and there, no doubt, will be some extension of this field also. Associated with this is the general idea of heating an atmosphere in an auxiliary oven and then circulating it around the metal to be heated — an idea equally applicable to high temperature as to low.

Suggestions have recently been made that we have before us great possibilities in the electric induction heating of ferrous products with or without prepared atmospheres and in this writer's opinion there is much merit in these thoughts. While the apparatus appears expensive, the actual power used is reduced to a minimum. Speed of heating can be the maximum permitted by the product. Control is simple and such apparatus can be used to feed work at an economical pre-determined rate in order to get maximum production from auxiliary equipment.

Heating by means of the electrical resistance of the product to be heated with electrode contacts is already an established method on small work and perhaps offers some of the results anticipated for the induction method but where work is large, irregular and in semi-finished state, mechanical problems are encountered.

As with the fuel burning methods, control pyrometers have reached a point of commercial perfection. Regular or irregular rates of heating or cooling can easily be provided if desired. Thermocouples are quite satisfactory and lately improvement has been made in this direction. The electric eye, or more properly the photo-electric cell, will undoubtedly supersede the millivoltmeter and potentiometer in controllers and now only awaits further development of automatic heating and feeding of product.

Gas analysis apparatus either of the continuous or sample testing variety is comparatively simple and satisfactory and can be expected to come into much more general use in metal heating plants. The so-called Wheatstone bridge type of gas analyser, which gives instantaneous and exact readings but is at present of limited life because of deterioration of materials within the apparatus, undoubtedly will be improved and when the improvement has been made, its use by sellers of fuel should be as general as the foot-candle meter used by the sellers of electricity for illumination.



At present, our metallurgical heating fuels and controls are in a highly satisfactory

Toolsteels for Hot Working Iron and Steel

By H. E. Replogle, Crucible Steel Co. of America

Requirements for All Hot Work Tools:

1. Of sufficient toughness to resist working stresses.
2. Of such composition and in such heat treated condition as to resist softening when in service.
3. To have adequate wear resisting properties to assure normal, economical life.
4. Of such composition and heat treated condition as to wholly or partially resist the tendency towards heat or fire checking.

Influence of Design:

1. Wedge designs, sharp corners and thin sections promote chances of breakage and require inherently tougher compositions, usually secured through lower total alloy content steels.
2. Designs including raised sections partially or wholly buried in hot metal require types of higher red hardness and may not require as high toughness characteristics as other wedge designs.

Importance of Mechanical Set-Up:

1. All forging dies should be properly lined up.
2. Machines should be true to assure uniform application of pressure or impact.
3. Dies should be so adjusted in hand fed and automatic forging machines as to prevent excessive pressure being developed on the faces of the dies, thus decreasing probability of fatigue failures.
4. Dies should not be mounted in worn or warped shoes or holders.

Importance of Adequate Preheating:

1. Well warmed dies and tools are less susceptible to cracking.
2. Minimum temperatures secured through use of buried unit heaters in certain types of drop forging dies prolong service life and retard heat checking.

Importance of Cooling:

1. Methods of cooling—Air, Oil, Water. Retards localized heating which may exert a tempering and softening action.
   a—Air cooling least drastic—applicable to all types of tools. Also serves to blow away scale which, if present, will cause undue wear of dies.
   b—Oil cooling—somewhat more severe and rapid but rarely detrimental to any tool or die.
   c—Water cooling—most effective, but very drastic and often dangerous. When large dies attain high temperatures, water cooling tends to cause heat checking. Punches and small dies are often successfully cooled with an ample flow of water.

Influence of Die and Tool Lubrication:

1. Heavy graphite bearing greases serve as lubricants and prevent sticking. Usually assures better wear.

Quenching:

Among the data given below are recommendations as to the quenching medium; oil, air and "oil & air". The words "oil & air" signify an interrupted or timed quench. With this method, a tool or die is quenched in oil to a temperature of about 1000° F., or where all color disappears. When this state is reached, the tool or die is removed and allowed to cool naturally in still air until cool enough to be handled in the bare hands. It should then be drawn as directed.

Recommended Compositions, Heat Treatments and Hardnesses

Analyses, %								Heat Treatment (°F.)				
C	Mn	Si	Ni	Cr	V	W	Mo	Pre-Heat	High Heat	Quench	Draw	Brinell Hardness
Insert Dies in Upsetters												
0.55	0.25	....	....	1.25	0.18	2.75	....	1400	1750	Oil	1200	400 to 450
0.55	0.35	....	....	4.00	1.00	....	0.50	1200	1650	Air	1150	400 to 450
0.30	0.30	....	....	3.25	0.25	9.00	....	1450	2150	Oil & Air	1200	400 to 450
0.25	0.20	....	....	4.00	0.50	15.00	....	1550	2350	Oil & Air	1200	400 to 450
Presses, Preloaded Dies												
0.40	0.30	....	....	1.75	0.18	11.00	....	1550	2150	Air	1100	539 to 578
0.45	0.30	....	....	2.75	0.40	15.00	....	1550	2200	Air	1150	539 to 578
Gripper Dies for Hand Fed Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1750	Oil	1100	450 to 500
0.55	0.30	0.40	....	4.00	1.00	....	0.50	1200	1650	Air	800	450 to 500
0.30	0.30	....	....	3.25	0.25	9.00	....	1200	2150	Air	1150	450 to 500
0.25	0.30	0.25	2.10	2.60	0.30	9.50	....	1450	2150	Air	1150	450 to 500
Gripper Dies for Automatic Machines												
0.40	0.35	1.00	....	5.00	0.50	....	1.50	1200	1800	Air	1075	444 to 526
0.55	0.35	....	....	4.00	1.00	....	0.50	1200	1625	Air	1000	444 to 526
0.30	0.45	0.95	....	4.25	....	1.25	1.65	1200	1850	Air	1100	450 to 500
Header Dies for Hand Fed Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1800	Oil	1225	430 to 461
0.30	0.30	....	....	3.25	0.25	9.00	....	1450	2150	Air	1175	430 to 461
0.30	0.45	0.95	....	4.25	....	1.25	1.65	1200	1850	Air	1100	400 to 450
0.25	0.30	0.25	2.10	2.60	0.30	9.50	....	1450	2150	Air	1200	400 to 450
Header Dies for Automatic Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1800	Oil	1250	388 to 429
0.40	0.30	....	2.50	2.25	....	....	....	1200	1800	Air	900	388 to 429
Forging Punches												
0.30	0.30	....	....	3.25	0.25	9.00	....	1500	2250	Oil & Air	1175	425 to 450

The above data do not represent all of the types being used for the various applications listed, nor do they represent the only heat treatments or hardness values for these types. Neither do the above listings include flat, cut and swaging dies used in beam, steam or air hammers. However, the types and treatments listed represent the broadest general selections being used commercially today in the services noted.

state. They are ready for increased work load. Behind the scenes the eager and restless have new possibilities in the development and assembling of the new apparatus which can now be visioned to give us old products that are better or cheaper or give us the new products that we cannot make with today's methods.

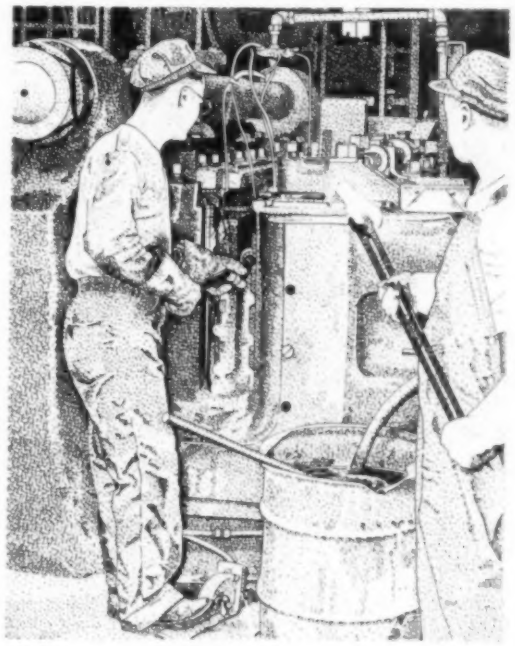
"Time marches on!"

Surface Cleaning of Forgings

By John A. Webber
Metallurgical Engineer
Interstate Drop Forging Co., Milwaukee, Wis.

THE USUAL METHODS of cleaning, namely tumbling, pickling, and blast cleaning, are still the most commonly used for cleaning forgings. In blast cleaning the trend is still toward the method using centrifugal force. The chief reason for this is because it requires considerably less power than the compressed air method. It is also well adapted to a combination of tumbling and blast cleaning. Some operators prefer a mixture of sand and shot, thinking that the action is faster and therefore cheaper.

A method of loosening the scale when heat treating forged steels is to use carbon tetrachloride in the heat treating furnace atmosphere. The loose scale is then easily removed from the heat treated parts and the cleaning cost is reduced, at an expenditure of about one quart of chemical per ton of forgings. A brick is usually soaked in carbon tetrachloride and thrown in the furnace after the parts have reached the heat treating temperature. This method is particularly useful for the higher nickel steels which ordinarily form a tight adhering scale. The method, however, must be used in well-ventilated premises, since carbon tetrachloride burns in the furnace and gives off free chlorine gas.



Chlorine seems to be the active element, because a few years ago some publicity was given to the scheme of loosening scale on normalized forgings with sizable flat areas (such as front axles for automobiles) by dipping them in chloride solution just before entering the hardening furnace. The scale appeared to loosen while at the hardening heat so it could be easily jarred loose. [See also the note on "dry pickling" with chlorine gas, page 382.]

A recent proposal for the descaling of billets with oxy-acetylene flame may have some interest in this connection. Multi-flame tips are mounted on a carriage in such number that they cover the surface to be de-scaled, and a fairly rapid traverse cracks off the scale as a result of its rapid thermal expansion. Wire brushing leaves a tinted, warm surface, said to be an ideal base for painting or lacquering.

Die Design and Die Steels

By H. E. Replogle
Crucible Steel Co. of America
Sanderson Bros. Works, Syracuse, N. Y.

WHEN TAKING STOCK of the improvements shown at the end of the year in any particular field, it is seldom found that these improvements are spectacular. Rather, there seems to be a general movement upwards which results in small but important savings, as well as higher quality products. This would seem to be the case in the field of forging dies.

As regards material handling, active and carefully planned experimental work is proving the benefits to be derived from closer control of temperatures and atmospheres in furnaces used in heating forging stock. Within practical limits, it is apparent that the proper selection of forging temperatures and atmospheres permits forging to be done with desirable flow characteristics as well as minimum die wear. Each general type of steel seems to have a "critical" as regards the combination of temperature and atmosphere which consist-

ently gives good results as far as speed of production and die costs are concerned.

Requirements for more accurate forgings plus better forging equipment have caused the forger to turn more and more to insert dies, using higher heat and abrasion resistant die steels. Accurate fits between dies, bolsters and machine or hammer are now accepted as being necessary and of exceptional influence on die life. Care in mechanical set-up is being stressed by all good forging concerns.

A practice adopted completely by some organizations has been the use of "pre-cracked dies", or dies made in sections and parted at the line of greatest stress or weakness, and assembled into a rigid block. This has allowed the use of hot work steels of higher red hardness and abrasion resistance than would be possible with a solid die, as well as dies at higher hardnesses than ordinarily thought possible. This practice should be seriously considered and studied by all in the forging field.

The influence of pre-heating and die temperatures is being studied extensively. Indications are that minimum die temperatures should be maintained. In some cases this has been accomplished through the use of buried unit electric heaters. Such dies are reported as definitely less subject to heat checks than dies allowed to become cold between shifts or which have steep temperature gradients in the die proper when forging begins.

The relationship of surface finish and resistance to heat checking, as well as the relationship between hardness and heat checking has been clearly established. Peter Payson, head of our Research Laboratory, finds that specimens subjected to an accelerated test develop checks in conformation with the line of polishing. As regards hardness, he has also shown that within working limits of hardness of certain of the tungsten-bearing hot work steels, hard specimens are no more susceptible to heat checking than softer ones. Additional research along this line is definitely scheduled and this should amply justify original work on the part of die designers to produce dies where stresses are minimized, and should encourage the production of dies as free from tool marks as is commercially practical.

During the past year the position of the 9% tungsten hot work steel seems even better established than hitherto. This is particularly noticed in the field of punches for hot metal, as well as insert dies for both ferrous and non-ferrous forging. Particularly in the field of gripper dies on automatic machines, the intermediate chrome-vanadium-low molybdenum type of hot work steel seems to have a favorable combination of toughness and wear resistance. In the field of forging dies proper, the intermediate chrome-tungsten-molybdenum type possesses excellent resistance to both wear and heat checking.

It would appear that further improvements during the coming year will be contributed mainly by the forging equipment builder, the die designer and the forger himself. Hot work steels of the higher alloy types have been successfully applied on practically every difficult forging problem. It remains for the industry to improve on these advances, applying them to their own problems as rapidly as possible.

Massive Forgings

By John L. Cox
Chief Engineer, The Midvale Co.
Philadelphia

IN the business of massive forgings there has been but little change in the situation described last year.

Plant for the production of large weldless rings, of which the prospective installation was then announced, has now been completed and is in operation.

The needs of the rapidly expanding Navy necessitate an increase in the existing equipment for the prompt production in quantity of the large forged parts required, which is now under way.

The tempo of business in heavy forgings has been distinctly quickened by this Governmental activity.

Drop Forgings of Steel

By Waldemar Naujoks
Chief Engineer
Steel Improvement & Forge Co.
Cleveland, Ohio

A GLANCE IN RETROSPECT reveals revolutionary changes in forging practice and technique during recent years. All types of forging equipment have shown valuable improvements. A new gravity drop hammer, using a steel rod instead of boards, was intro-

duced recently. Forging materials number many additions including leaded carbon steels, an augmented commercial list of structural alloy steels, increased variety of stainless irons and steels, and many new compositions in the nonferrous forging metals.

Designs of forged parts show many new and more complicated shapes with reduced permissible draft. This is accompanied with specifications for selected grain sizes and grain structure as well as narrowed composition ranges. Inspectors ask for improved surface conditions and closer tolerances. Forging practice has covered, indeed, much ground during a short span of time in striving to maintain its reputation of being as reliable and strong as Gibraltar.

Several basic problems are receiving serious consideration. Newer and tougher forging metals demand improved die steels over those which are highly alloyed now. Leaded alloy steel blocks have been tried to permit machinability at higher hardnesses for greater die wear; it is too early to appraise the results.

Attention has been given to furnace design, temperatures, and atmospheric control in the belief that improved furnace conditions may solve some of the forging difficulties on the tougher and more sensitive metals.

The demand for cored and undercut sections in forged parts has led to some work in arc welding two or more forgings together. Through improvements in forgings and the arc welding process, continued experiments can develop some interesting and useful results by which welded forgings will show merit for many applications.

Light Metal Forgings

By A. A. Handler
Aluminum Co. of America, Cleveland, Ohio

FROM THE STANDPOINT of total tonnage purchased over a period of years, the aircraft industry has been by far the outstanding market for aluminum alloy forgings. Its steady demand for strong, light weight parts has been a major impetus to the development of new alloys and forging technique. In turn, these improvements have increased the range of characteristics of aluminum forgings and hence the kinds of applications have greatly increased.

From propeller blades and engine parts, the use of aluminum forgings in aircraft spread to stressed fittings, wing spars and main parts of landing gears. The service record of the older applications, especially that of propeller blades, has been most noteworthy. New alloys introduced since the earlier ones were first used, combined with improved techniques, have made possible forgings that are remarkably intricate.

Strong aluminum alloy forgings now have a background of many years' experience in the aircraft field. This record of successful performance has paved the way to applications in other fields to such an extent that uses other than aircraft (as well as in aircraft) have shown important gains.

To illustrate the wide diversity of applications, one can cite such things as hack-saw frames, typewriter levers, supercharger impellers, rayon spinning buckets, trowel handles and diesel engine pistons.

Aluminum alloy forgings have definitely won their spurs among the common forms of strong, light weight metal parts available to the product designer. Their characteristics and application possibilities are definitely known, and they should be considered wherever a high strength, light weight part of uniformly dense structure is desired.

Pressings, a relatively new form of forgings in aluminum alloys, have likewise made notable progress in the past few years. They are made of heat treated alloys, are often surprisingly economical and, because they are pressed — that is, formed in one stroke of a press rather than by repeated blows of a hammer — may be produced with dimensional tolerances much closer than are ordinarily possible with hammer forgings. Closer tolerances not only reduce the amount of metal per piece but also reduce

machining time and cost. In fact, for many pressings machining is eliminated altogether. In addition to being uniformly strong and sound, they are highly resistant to corrosion.

While the use of magnesium alloys is more widespread abroad than in this country, magnesium alloy forgings have been currently developed along with aluminum forgings and are becoming recognized for their unique combination of extreme light weight and good strength. Here again the demands of the aircraft industry have stimulated development, and every year is finding more and more use for magnesium alloy forgings.

Forging the Nickel Alloys

By Fred P. Huston
Development & Research Division
International Nickel Company, Inc.
New York City

PRODUCTION of sheets, tubes, rods, and other rolled and drawn forms of nickel and the high nickel alloys in our works depends upon the forgeability of these materials. Forging of the ingots by hammering is the first operation following casting and overhauling. This is done in order to break down the cast dendritic structure, a matter usually accomplished in ferrous and most other non-ferrous materials by rolling. The standard ingot cast at the Huntington (W. Va.) mill is 14 in. square in cross section and weighs about 3000 lb. Rectangular ingots for forged slabs used for the rolling of hot rolled plate and special ingots for heavy hammer forgings are produced in weights to 13,900 lb.

The ingots are heated in sulphur-free gas-fired furnaces under pyrometric control and proportioned gas-air atmospheric control. The temperature is controlled at about 50° F. higher than the forging temperature and the atmosphere is controlled at about 1.5% CO.

Forging is done under a 16,000-lb. steam drop hammer with rapid, full force blows. The 14-in. square ingots are brought down to 8x8 in., 11x4 in., and similar sized billets for the merchant mill.

The ideal conditions of heating and forging nickel and the trade-named alloys Monel and Inconel in the manufacturer's works, are approached closely in many plants throughout the country producing both drop hammer and die forgings. A relatively small number of plants have available the ideal gas fuel for heating, but equally good results are obtained with low-sulphur oil fuels in properly designed furnaces. These shops meet the required conditions of temperature and atmospheric control, rapid heating, minimum time allowed for soaking, and hard and rapid working to accomplish as much reduction as possible on each heat so as to limit the number of reheats.

Virtually any forged shape now obtainable in ferrous and other non-ferrous materials can be produced in nickel and the high nickel alloys by following the practices outlined above.

Although the hot extrusion of nickel and high nickel alloys has not been given a great deal of attention in this country, such sections as tubes, turbine blading, rounds, and irregular shapes, are being hot extruded in regular production abroad. The heaviest sections are produced in hydraulic extrusion presses of 2000 tons capacity.

Another advance has been made in the production of forged rounds of high tensile regular Monel for shafting, and other shapes for special purposes, by cold hammering, that is, hammering at temperatures under about 1100° F., to yield good properties in this lower priced metal. A typical example of the properties obtainable is represented in a test on a gate shaft 6 in. in diameter. A test piece cut from the center of one of these Monel shafts showed a yield point of 74,500 psi., a tensile strength of 99,000 psi. with 34.5% elongation in 2 in., and 60.4% reduction of area.

FURNACES

AND

REFRACTORIES

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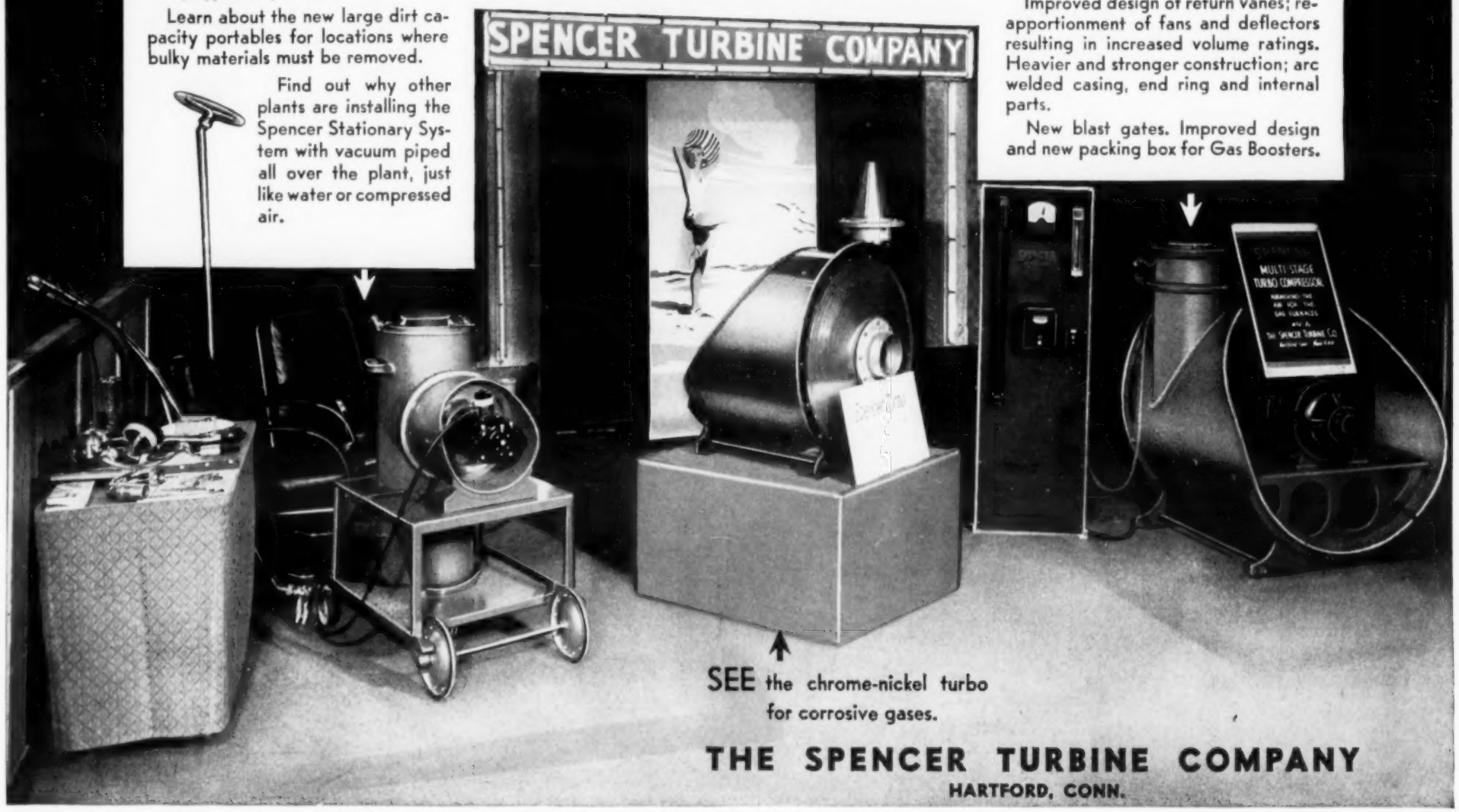

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Furnaces and Refractories

Refractories in Prospect

By J. M. McKinley
Vice-President, North American Refractories Company
Cleveland, Ohio

TECHNICAL and trade paper literature bearing upon refractories and their applications industrially, published in the last few years, has been voluminous. The data presented formulate a new comprehension of the essential character of refractories. Prior to 1930 it may be assumed safely that the refractory producers comprised one of the numerous heavy goods industries turning out a bulk product; as rapidly as scientific and engineering data could be assimilated various lines of refractories were improved and new ones created, tending to convert all types of refractories plants to producers of shop specialties. The past ten years has been a conversion period with the industry literally in a state of flux. The most significant trend, in fact the governing trend, in this whole development has been the patent fact that refractories as utilized in most of our major industrial operations became the key to low costs as well as improved products. Even the most sanguine review of the past ten years cannot assume that either the producer of refractories or the consumer has as yet consolidated his gains.

Twenty years ago the industry realized that a fire brick was not "just a fire brick". Step by step fire brick makers have become conscious of the infinite variety of service requirements leading to the development described in the foregoing paragraph. From rudimentary methods of determining a suitable refractory for a given service, the industry began its attempts to correlate service conditions with logically engineered materials. Looking forward, it is obvious that this method of handling refractories will dominate the future.

This situation is so obvious that recently it has been taken for granted by both producer and consumer to such an extent that some vital factors are being overlooked. From the very start of the movement it was plain that refractories producers would be confronted with plant obsolescence to an increasing degree, yet it is doubtful even today if the full extent of this fact is appreciated. For example, size tolerances have been narrowed steadily, and this of itself is causing a revision of process. A further difficulty of major importance has arisen from the introduction of new refractory materials, some fabricated on definitely new systems and others blended with older standard materials. The ultimate adjustment of this factor is now far from accomplished, and it probably represents the greatest problem before our industry since it involves radical revision of equipment and production methods.

Heavy capital expenditures are indicated in the next decade, as well as the complete revision of the economic structure in the industry. Examination of the production flow sheet of

typical plants of ten years ago reveals considerable simplicity, which is being slowly eradicated by the new variables entering the market, so that an up-to-date plant must now represent not only an increased capital investment but a lower production yield on the same or comparative capital investment.

This metamorphosis of the industry is the product of consumer demand and it is to be hoped that, in the forthcoming period of development, the consumer will keep alert to an obligation which he himself owes the refractory makers. Every adaptation of a given refractory to a service condition primarily involves complete engineering data covering the consumer's requirements in a particular unit, but consumers have not been nearly so keen to supply these data as the refractory producer has been to supply a better fire brick. This, of course, is not universally true, but it is true enough in a sufficiently large number of cases to make the point worthy of mention.

Trial-and-error methods characterized the earliest endeavors to improve the service of refractories, and these methods still prevail to some large extent. It is not sufficient for the needs of the case that the consumer should provide adequate control apparatus in his own operation; it is equally mandatory that he know the fundamental reactions involved in the relationship of his processing to the refractory in use. A typical instance is found in the blast furnace where it is conceded that a more efficient brick is needed in the bottom blocks and especially in the lower inwall; yet in both cases fundamental data are lacking and it is only recently that blast furnace operators have set themselves to study these conditions.

The full significance of this problem is best revealed when attempts are made to draw specifications. These obviously must be based on test procedure of a purely laboratory character or upon some type of simulative service. Fundamentals of our present specifications must be recognized as more or less inadequate, and fire brick users —along with producers— have a difficult task ahead of them in correlating service conditions with some type of control testing. Existing efforts must be viewed as an approximate solution of the problem. The consumer has a big stake in this development because, in industry after industry, the limiting factor of development is frequently the problem of the necessary refractories.

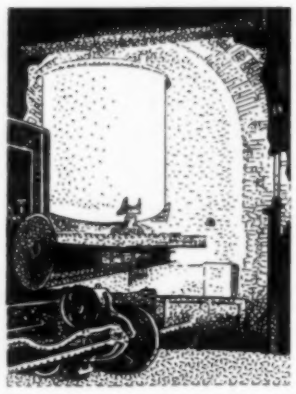
Progress made in the last ten years has laid a fine foundation for developments in the next ten years. Even limited experience with the problems involved reveals an increasing friendliness and cooperation between those engaged in the work. Attempts to interpret existing data result in a great deal of confusion, and it is highly worth while to note that the industry is working ahead with the right sort of human understanding. Such an understanding must embrace appreciation of the severe economical dislocation which can occur in a supply industry that is confronted with the problems now before the producers of refractories.

High Temperature Refractories

By John D. Sullivan
Chief Chemist, Battelle Memorial Institute
Columbus, Ohio

ONE OF THE GREATEST BOONS to the metallurgical industry has been the development and improvement of special high temperature refractories. These may take the form of pre-fabricated shapes or of loose materials to be used for the construction of furnace parts, for repairing, or use in conjunction with fabricated forms. An additional classification is that of special or rarer refractory materials for crucibles and induction furnace linings, and for containers that will not react with or contaminate their molten contents.

Most metallurgists are familiar with prefabricated forms of high temperature refractories, such as brick, tile, block, and special shapes consisting principally of silicon carbide, corundum, and mixtures based on the sillimanite group of alumino-silicate minerals. Somewhat less familiar to metallurgists, but common to glass manufacturers, are electrically fused mullite blocks used extensively in the construction of glass melting tanks. These pre-fabricated shapes are used ordinarily where some specific property is required — for example, high refractoriness, resistance to corrosion, erosion or abrasion, high thermal



conductivity, or unusual load-bearing ability at high temperatures.

In many respects, however, the special refractories of much more interest to the metallurgical industry are granules or mortars, not pre-fabricated into shapes. These may, in general terms, be classed as mortars, coating materials, ramming mixes and castables (although the last-named group cannot be used where extremely high temperatures are involved). They may take the form of acidic, neutral, or basic mixes. Remarkable advances have been made in the last decade in all these products, and improved and new products have contributed in no small measure to recent metallurgical achievements.

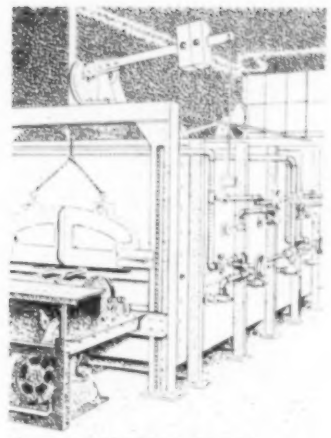
There has been a general improvement in high temperature bonding mortars, brought about in part by greater attention to grain size and to the selection of proper materials for a particular job.

Ramming mixes are perhaps the most interesting of the special refractories, and are used both for the original construction of furnace units and for patching to prolong furnace life. Extreme care is exercised in the selection of proper grain size and in making the mixes workable. Among these materials raw or calcined cyanite is finding extensive use in the alumino-silicate mixes.

A good example of a ramming mix that has contributed to the metallurgical industry is the plastic chrome used for basic openhearth furnace bottoms. So important has this become that practically every bottom now being put in employs this type of mixture. Ramming mixes are also used extensively in the construction of the bottoms of heating furnaces. There has been a gradual improvement in the quality not only of chrome but also of magnesia and alumino-silicate and other high temperature ramming mixes.

Crucibles and induction furnace linings, while used in smaller tonnages, are nevertheless important both to the metallurgical and ceramic industries. Marked advances have been made in manufacturing technique and in the properties of the products. Crucibles composed principally of magnesia, zirconia, beryllium oxide, corundum or mullite are readily available, at least in the smaller sizes.

The metallurgical industry can look forward to continued improvements in special refractories, and the refractories manufacturer can likewise expect extension of their use.



Insulation

By J. B. Austin
Kearny, N. J.

THE FIELD OF INSULATION for temperatures above 2000° F. remains about where it was a year ago, no new or outstanding products of general application having been developed recently. There is, however, one special material that deserves mention, namely, ceramic-covered cork granules for use on top of ingots during freezing. It has been stated that by their use ingot tops are kept molten for 65 min., as compared with 12 min. when sand is used.

In contrast to the relative inactivity in the high temperature field, there have been marked advances in insulation for temperatures below 2000° F. For example, there has been a great increase in the use of mineral wools which are mixed with asbestos fiber, clay or other suitable materials, and are made into blocks, bricks or coatings. The physical properties and thermal resistance of these products have been substantially improved. A number of different kinds of wool are now being used, including rock wool, glass fiber, and slag wool made from iron, lead or copper slags. The phenomenal growth of the mineral wool industry is well illustrated by the fact that within the last five years the value of the annual production has increased from $1,700,000 to some $30,000,000. About two thirds of this output now goes into insulation for buildings, but an increasingly larger percentage of it is being used for high temperature insulation, and much attention will probably be given to this application during the future.

The use of expanded mica (vermiculite) granules is likewise increasing. This material, which is available in a number of different

Properties of Refractory Materials, Except Fireclay

Compiled by Stuart M. Phelps, and Copyrighted 1935 by American Refractories Institute, Technical Dept., Mellon Institute.

Material (1)	Composition of the Pure Material		Melting Point	True Specific Gravity	Hardness (Moh's Scale)	Mean Specific Heat (17)	Thermal Expansion (Note 22)	Thermal Conductivity (2)		
	Formula	Composition %						At 1000° F.	At 1600° F.	At 2400° F.
Andalusite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.20	7.5	0.168 (18)	6.2*			
Chromite	$FeO.Cr_2O_3$ (3)	Cr_2O_3 68 FeO 32	2180° C. 3956° F.	4.5	5.5	0.22*	8.0*	10.0*	10.9*	12.1*
Corundum	Al_2O_3	Al_2O_3 100	2050° C. 3722° F.	4.0 (24)	9	0.304*	8.5	23.0*	26.5*	30.0*
Cyanite (Kyanite)	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.6±	4 to 7		4.9* (4)			
Diasporite (Diaspore) (5)	$Al_2O_3.H_2O$	Al_2O_3 85.1 H_2O 14.9	2050° C. 3722° F.	3.4 to 3.5	6.5 to 7	(Note 6)	6.5*			
Dolomite	$CaCO_3.MgCO_3$	CaO 30.4 MgO 21.9 CO_2 47.7	(Note 23)	2.81 to 2.95	3.5 to 4.0	0.222 (19)	14.0			
Dumortierite	$8Al_2O_3.6SiO_2.B_2O_3.H_2O$	SiO_2 64.6 Al_2O_3 28.5 B_2O_3 5.5 H_2O 1.4	1810° C. 3290° F.	3.30	7		5.2*			
Forsterite	$2MgO.SiO_2$	MgO 57.3 SiO_2 42.7	1910° C. 3470° F.	3.22	6 to 7	0.22 (19)	10.5*	11.1*	10.6*	10.3*
Graphite	C	C 100	>3000° C. >5432° F.	2.25	1 to 2	0.29	2.2			
Magnesia spinel	$MgO.Al_2O_3$	MgO 28.2 Al_2O_3 71.8	2135° C. 3875° F.	3.6	8	0.257	8.5	12.2*	13.3*	14.5*
Mullite	$3Al_2O_3.2SiO_2$	Al_2O_3 71.8 SiO_2 28.2	1810° C. 3290° F.	3.03		0.175 (20)	5.3 (7)			
Periclase (Magnesia) (8)	MgO	MgO 100	2800° C. 5072° F.	3.64 to 3.67	5.5 to 6.0	0.285	13.5*	19.5*	15.5*	13.0*
Quartz (9) (Quartzite)	SiO_2	Silica 100	1400° C. (10) 2552° F.	2.653	7	0.263*	32.6* (11) 4.6 (12)	8.8*	10.7*	13.3*
Silicon carbide	SiC	Si 70 C 30	2250° C. (13) 4082° F.	3.17 to 3.21	9 to 10	0.19 (14)	5.2 (15)	142*	110*	80*
Sillimanite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.24	6.5 to 7.5	0.175				
Zircon (Zirconium silicate)	$ZrO_2.SiO_2$	ZrO_2 67.1 SiO_2 32.9	2550° C. 4622° F.	4.7	7.5	0.132 (21)	4.5			
Zirconia (Zirconium oxide)	ZrO_2	Zr 73.9 O_2 26.1	2700° C. 4892° F.	5.5 to 6.0	6.5	0.16	6.6 (16)	12.0*	13.0*	14.0*

*1. These properties refer to pure materials and not to commercial refractories which may differ because of impurities, bonding materials, and process of manufacture. The specific heat, thermal expansion and thermal conductivity data, however, may be used for engineering purposes and especially those marked with asterisk (*) which were obtained from commercial products.

2. Thermal conductivity in B.t.u. per in., per hr., per sq.ft., per °F., averaged from the more reliable data on refractories.

3. General chemical formula for chromite is $RO \cdot R_2O_3$. The RO oxide is usually FeO and may be replaced in part by MgO, while the R_2O_3 is mostly Cr_2O_3, but may be replaced in part by Al_2O_3 and Fe_2O_3.

4. Indian.

5. Commercial diaspore is composed of diasporite grains bonded with clay.

6. Probably close to 0.26.

7. Synthetic, pure.

8. Magnesite is amorphous, or crystalline like periclase, depending upon the heat treatment it has received.

9. Ganister is the commercial form for use in refractories, about 98% silica.

10. Crystobalite is the stable form of silica above 1470° C., and has the melting point of 1713° C. (3115° F.).

11. Value is for silica brick, mean expansion in range 20 to 300° C.

12. Value is for quartz, mean expansion in range 300 to 1135° C.

13. Dissociation temperature; oxidation may begin at 900° C. (1652° F.).

14. Varies with temperature.

15. This figure, and those for thermal conductivity, are for recrystallized material.

16. Pure material sintered.

17. For the range 20 to 1000° C. (68 to 1832° F.) unless noted.

18. For the range 0 to 100° C.

19. For the range 20 to 100° C.

20. For the range 20 to 800° C.

21. For the range 21 to 51° C.

22. Values for the mean reversible thermal expansion per ° C. times 10^6, for the range 20 to 1000° C. unless noted.

23. Dissociates at very high temperatures.

24. Alpha modification.

forms, will undoubtedly find wider application in the near future.

To the group of materials for use at temperatures up to 900° F. two interesting products have been added. The first is an asbestos-silica board originally intended as a fireproof wall material for ships. It has strength enough for screws and nails to be driven into it, is proof against fire and moisture, and yet has a very low thermal conductivity. This material has promise as an insulator for ovens or any other application in which the maximum continuous temperature does not exceed 900° F. The other development is the iron oxide, calcium sulphate insulating block or board made by treating waste pickle-liquor with lime. In view of its low thermal conductivity and the fact that it

utilizes a waste product, this material is attracting considerable attention.

The newly developed silica aerogel is remarkable because of its low thermal conductivity, the conductivity of some samples being less than that of still air. This material is transparent to infra-red light and must be made opaque by addition of finely ground silicon before it can be used above room temperature.

The much-debated question of whether the use of insulation may not increase the heat consumption in a furnace operating intermittently seems to have been settled. It is fairly evident now that the use of insulation does not lead to a higher heat requirement, for the extra heat lost by storage in the insulation would be lost through the wall if insulation were not used.

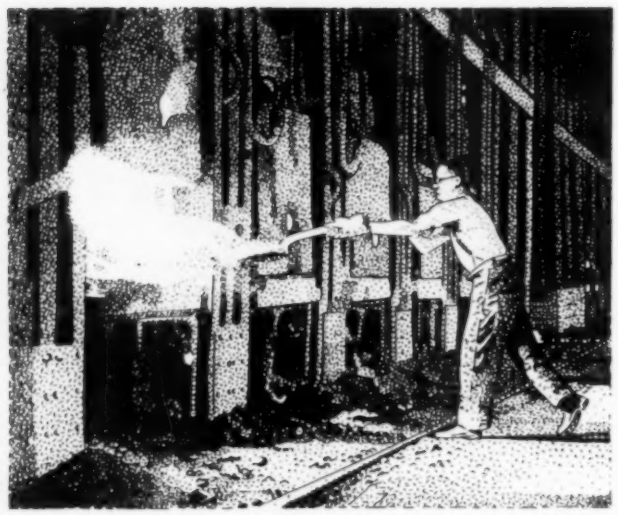
The prevailing dissatisfaction with methods of testing insulating material, and the increasing interest in fundamental data on variables influencing thermal conductivity, are reflected by the formation of a new Committee C-16 on Thermal Insulation Materials by the American Society for Testing Materials, and the fact that two symposia on thermal insulation have been scheduled by large technical societies. One sponsored by the American Society for Testing Materials was held in Columbus in March; another was held by the American Chemical Society at Baltimore in April.

One of the main problems facing those interested in insulation is improvement of methods of measuring thermal conductivity at high temperatures. A great deal has been accomplished in the past few years but much still remains to be done. In particular, the problems of how properly to measure the surface temperature of a specimen, of how best to measure the heat flow, and of how to prevent serious warping of the specimen because of the non-uniform distribution of temperature during test, have not been satisfactorily solved.

Combustion of Gas

By L. O. Howell
Industrial Engineer
American Gas Association Testing Laboratories
Cleveland, Ohio

THE ESSENTIAL REQUIREMENTS for satisfactory burning of gas for the production of heat are well understood and simple in nature, but constant care is necessary if the actual conditions are to be kept at the desired optimum. Combustion of gas may be completely controlled by the manner of mixing the gas and air. Short, high temperature flames involving high inputs per unit of furnace volume (as in certain boilers and chemical operations) and requiring water-cooled walls for proper utilization may be produced by completely mixing gas and air in the proper proportions *prior* to combustion. At the other extreme, introduction of either concentric or parallel layers of gas and air in the correct proportions, as for luminous flame and radiant tube furnaces, will produce a long flame having a highly uniform heat release over a large portion of its length. It is equally simple to heat large volumes of air or liquids to relatively low



temperatures, where it is desirable to maintain a small temperature differential between the heated material and the heating medium — as in convection heaters and certain cleaning or pickling operations. Whatever the requirements may be, whether established by limitations of refractories or by characteristics of the material being heated, a suitable gas mixing and combustion device is available, complete with controls.

Attention has therefore recently been more centered on certain chemical and physical problems involved in combustion. The problems of controlling the combined chemical and physical effects of the flue products on the heated work are much more difficult than the problems of controlling the thermal effect alone, but where finished surfaces are to be protected (or altered) at the same time they are heated, and the objects are finished to size and have limited tolerances — then chemical control becomes a necessity.

Realizing the need for fundamental information on the chemical characteristics of flue gases, the Committee on Industrial Gas Research of the American Gas Association has been studying the thermal and chemical aspects of combustion for a number of years. Bulletins 723, 746 and 748 of the A.G.A. Testing Laboratories present the results of earlier studies of the effect of oxidizing atmospheres on combustion. In these studies, rates as high as 9,000,000 B.t.u. per cu.ft. of combustion space were employed. While complete results are given in the various bulletins, it was found, for example, that only 1% oxygen or about 5% excess air was required in the products to repress completely the formation of CO and H_2 in the products at 2600° F., provided the gas and air were adequately premixed.

Our more recent investigations have been in the field of reducing atmospheres. They have covered all air-gas mixtures readily flammable in a water-cooled wall or ceramic wall furnace or burner tube, and having less than the amount of air theoretically required for complete combustion. Of course the oxidizing or reducing nature of such atmospheres may depend on the characteristics of the heated material as well as on the proportions of air supplied.

Although the investigation of reducing atmospheres has not been completed, it is apparent that such atmospheres are chemically much more "fluid" than oxidizing atmospheres, because of their sensitivity to temperature changes and rates of temperature change. The $CO:CO_2$ ratios and other important chemical characteristics may be changed by temperature changes, and "frozen" at desired values by quick cooling prior to the removal of water vapor or other treatment. Whether the products are to be used directly or treated, changes in input must be made with great care, since the resulting changes in temperature gradient may change the chemical composition of such a variable and complex gas mixture. Where treated and untreated mixtures are brought in contact with cold work to be heated or hot work to be protected or surface treated, consideration must be given to the temperature history of the gases before contacting the work if undesirable chemical or thermal results are to be avoided.

All indications point to a need for careful adjustments and precise control of all conditions in the utilization of reducing atmospheres. Their potentialities have barely been approached. Some of the difficulties experienced in this field have arisen from a failure to realize the intimate relationship between temperature, time, and chemical composition. If temperature changes are too rapid, changes in chemical composition may lag until accelerated by contact with the work. Where these relationships have been appreciated, knowledge of combustion fundamentals has often been so limited that results could not be predicted.

In the face of such obstacles, great improvements have been made in equipment for production and control of special atmospheres from fuel gases. Apparatus is now available for the preparation of atmospheres highly useful in many specific applications.

Clean Blast Furnace Gas

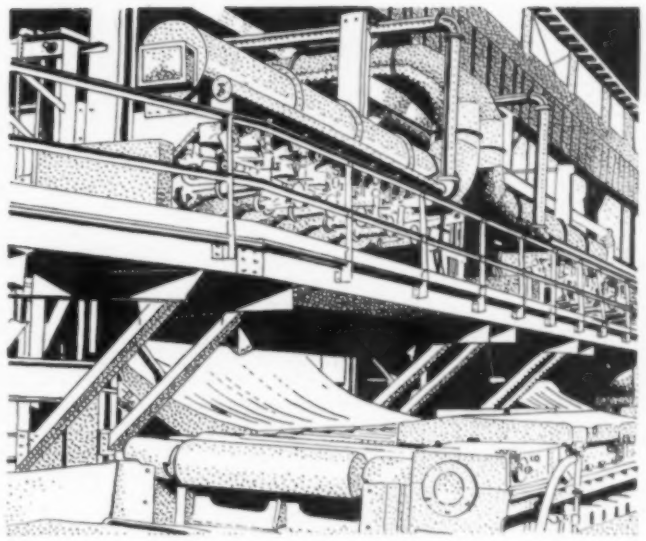
By P. F. Kinyoun
Combustion Engineer, Bethlehem Steel Co.
Lackawanna, N. Y.

IN THE MODERN STEEL PLANT, blast furnace gas is used for heating hot stoves, in engines for blowing the furnace and generating electric power, and as fuel for boilers, metallurgical and heating furnaces and coke ovens. In most plants, the entire production of gas is first cleaned in primary static washers and then some portion further cleaned in secondary units, such as disintegrators, electric precipitators, or drum-type Theisen cleaners. The primary cleaned gas — which carries from 0.15 to 0.20 grains of dust per cu.ft., as well as entrained moisture — is usually sent direct to hot stoves and boilers. That portion of the total for engines, heating or metallurgical furnaces and coke ovens, is further cleaned by one of the methods mentioned above. This secondary cleaned gas contains from 0.01 to 0.015 grains of dust per cu.ft. and is practically free of entrained moisture.

Even though primary cleaned gas is used in many plants in the hot stoves and boilers, it is done with a penalty. Due to its high dust and moisture content, modern small-checker hot stoves cannot be used and, in a boiler plant, the cost of upkeep is high and the efficiency is low. Some plants have therefore installed secondary cleaning equipment. Its first cost is high and the cost of operation, with the exception of the electric method, is approximately four times that of a static washer, depending somewhat on the unit cost of electric power and water. Disintegrator cleaned gas for the hot stoves of a 1000-ton blast furnace will increase the cost of cleaning as much as $10,000 per year.

Gas with low dust content (0.01 to 0.015 grains per cu.ft.) is a desirable fuel for both hot stoves and boilers, and is required for furnaces, coke ovens and engines, but it is believed that gas containing from 0.04 to 0.05 grains of dust per cu.ft. and free of entrained moisture would serve hot stoves and boilers equally as well as gas containing 0.01 to 0.015 grains.

The need in the industry today, therefore, is a primary washer costing about the same and with an operating cost about equal to the present static washer, but able to clean and deliver dry gas down to 0.04 to 0.05 grains of dust per cu.ft. Several full sized primary cleaning units



of a modified design are now in operation throughout the country and are reported to be delivering such gas with a great improvement in moisture content as compared to ordinary static washers. The cost of these washers is said to be approximately that of the conventional spray type and if fully successful should open the way to substantial savings in present cleaning costs for hot stoves and boilers now using finely cleaned gas, and increased efficiency for such units now using the usual primary washed gas.

Use of Open Flames

By E. G. deCoriolis
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Toledo, Ohio

APPLICATION OF A FLAME to a metal surface for the purpose of relieving strains at focal points has long been practiced. The most recent use made in the application of this old method is in the development of strand annealing for copper wire. Its particular virtue lies in the fact that copper can be heated and remain unoxidized if the enveloping atmosphere be devoid of free oxygen. As is well known, a burning gas flame, supported by a proper ratio of air to gas, is free from uncombined oxygen in that portion of the flame which is just beneath its extreme point. A strand of copper wire if passed through a continuity of such flames can be heated to annealing temperature without tarnishing its surface.

This scheme necessarily involves very accurate burner design and fabrication as well as

Combustion of Common Gases

Adapted (by permission) from tables in 1938 issue of American Gas Catalog and Handbook

Material, Formula and Reaction	Molecular Weight	Specific Gravity (Air = 1.0)	Density at 60° F., 30 In. Barometer		Specific Heat (H_2O = 1.0)	Heat of Combustion				Cu.Ft. per Cu.Ft. Combustible				
						B.t.u. per Cu.Ft.		B.t.u. per Lb.		Required for Combustion		Products of Combustion in Air		
			Lb./Cu.Ft.	Cu.Ft./Lb.		Gross	Net	Gross	Net	Air	O_2	CO_2	H_2O	N_2
Carbon, C (to CO) ..... $C+\frac{1}{2}O_2=CO$	12.010	.....	.....	.....	....	.....	.....	4,001	4,001	2.382*	0.5*	1.0* CO	...	1.882*
Carbon, C (to CO_2) ..... $C+O_2=CO_2$	12.010	.....	.....	.....	....	.....	.....	14,136	14,136	4.764*	1.0*	1.0*	...	3.764*
Carbon monoxide, CO ..... $CO+\frac{1}{2}O_2=CO_2$	28.010	0.9667	0.07402	13.509	0.243	321.7	321.7	4,346	4,346	2.382	0.5	1.0	...	1.882
Carbon dioxide, CO_2	44.010	1.5289	0.11707	8.542	0.203	.....	.....	.....	.....	.....	...	...	...	.....
Hydrogen, H_2 ..... $H_2+\frac{1}{2}O_2=H_2O$	2.0162	0.06951	0.005323	187.881	3.409	325.0	274.6	61,061	51,592	2.382	0.5	...	1.0	1.882
Paraffin Series, C_nH_{2n+2}														
Methane, CH_4 ..... $CH_4+2O_2=CO_2+2H_2O$	16.042	0.5548	0.04248	23.542	0.593	1,015.0	914.0	23,896	21,517	9.528	2.0	1.0	2.0	7.528
Ethane, C_2H_6 ..... $C_2H_6+3\frac{1}{2}O_2=2CO_2+3H_2O$	30.069	1.0468	0.08016	12.475	0.397	1,790	1,637	22,330	20,422	16.674	3.5	2.0	3.0	13.174
Propane, C_3H_8 ..... $C_3H_8+5O_2=3CO_2+4H_2O$	44.095	1.550	0.11866	8.427	0.365	2,572	2,366	21,675	19,939	23.820	5.0	3.0	4.0	18.820
n-Butane, C_4H_{10} ..... $C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.078	0.1591	6.284	0.351	3,393	3,132	21,321	19,681	30.966	6.5	4.0	5.0	24.466
Iso-Butane, C_4H_{10} ..... $C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.066	0.15815	6.323	0.351	3,364	3,105	21,271	19,633	30.966	6.5	4.0	5.0	24.466
n-Pentane, C_5H_{12} ..... $C_5H_{12}+8O_2=5CO_2+6H_2O$	72.147	2.49*	0.1907*	5.245*	....	4,023*	3,720*	21,101	19,511	38.112*	8.0*	5.0	6.0	30.112
n-Hexane, C_6H_{14} ..... $C_6H_{14}+9\frac{1}{2}O_2=6CO_2+7H_2O$	86.173	2.97*	0.2277*	4.392*	....	4,771*	4,418*	20,954	19,404	45.258*	9.5*	6.0	7.0	35.758
Olefin Series, C_nH_{2n}														
Ethylene, C_2H_4 ..... $C_2H_4+3O_2=2CO_2+2H_2O$	28.052	0.9747	0.07464	13.398	0.363	1,615	1,514	21,638	20,285	14.292	3.0	2.0	2.0	11.292
Propylene, C_3H_6 ..... $C_3H_6+4\frac{1}{2}O_2=3CO_2+3H_2O$	42.079	1.481	0.11340	8.819	....	2,380	2,226	20,990	19,630	21.438	4.5	3.0	3.0	16.938
Butylene, C_4H_8 ..... $C_4H_8+6O_2=4CO_2+4H_2O$	56.105	1.935	0.1482	6.750	....	3,079	2,877	20,780	19,420	28.584	6.0	4.0	4.0	22.584
Aromatic Series,														
Benzene, C_6H_6 ..... $C_6H_6+7\frac{1}{2}O_2=6CO_2+3H_2O$	78.109	2.712*	0.2076*	4.816*	....	3,758*	3,607*	18,100(a)	17,370(a)	35.730*	7.5*	6.0	3.0	28.230
Toluene, C_7H_8 ..... $C_7H_8+9O_2=7CO_2+4H_2O$	92.135	3.177*	0.2433*	4.110*	....	4,452*	4,250*	18,300(a)	17,470(a)	42.876*	9.0*	7.0	4.0	33.876
Xylene, C_8H_{10} ..... $C_8H_{10}+10\frac{1}{2}O_2=8CO_2+5H_2O$	106.161	3.661*	0.2803*	3.567*	....	5,189*	4,937*	18,510(a)	17,610(a)	50.022*	10.5*	8.0	5.0	39.522
Acetylene, C_2H_2 ..... $C_2H_2+2\frac{1}{2}O_2=2CO_2+H_2O$	26.036	0.907	0.06946	14.396	0.383	1,491	1,440	21,460	20,730	11.910	2.5	2.0	1.0	9.410
Naphthalene, $C_{10}H_8$ ..... $C_{10}H_8+12O_2=10CO_2+4H_2O$	128.165	.....	.....	.....	....	.....	.....	17,314(b)	16,718(b)	57.168*	12.0*	10.0	4.0	45.168
Ammonia, NH_3 ..... $NH_3+\frac{3}{4}O_2=\frac{1}{2}N_2+1\frac{1}{2}H_2O$	17.032	0.5966	0.04568	21.890	0.520	442	365	9,678	8,000	3.573	0.75	...	1.5	3.323
Nitrous oxide, N_2O	44.016	1.530	0.11712	8.538	0.221	.....	.....	.....	.....	.....	...	...	...	.....
Nitric oxide, NO	30.008	1.0365	0.07936	12.600	0.232	.....	.....	.....	.....	.....	...	...	...	.....
Hydrogen sulphide, H_2S ..... $H_2S+1\frac{1}{2}O_2=SO_2+H_2O$	34.076	1.1902	0.09114	10.973	0.245	637	586	6,992	6,432	7.146	1.5	1.0 SO_2	1.0	5.646
Sulphur dioxide, SO_2	64.060	2.2636	0.17333	5.769	0.154	.....	.....	.....	.....	.....	...	...	...	.....
Water vapor, H_2O	18.016	0.6220*	0.04763*	20.995*	0.48	.....	.....	.....	.....	.....	...	...	...	.....
Oxygen, O_2	32.0000	1.1051	0.08462	11.818	0.217	.....	.....	.....	.....	.....	...	...	...	.....
Nitrogen, N_2	28.016	0.9671	0.07405	13.504	0.244	.....	.....	.....	.....	.....	...	...	...	.....
Nitrogen ("Atmospheric") (c)	28.161	0.9721	0.07443	13.435	0.242	.....	.....	.....	.....	.....	...	...	...	.....
Air (d)	.....	1.0000	0.07657	13.060	0.2375	.....	.....	.....	.....	.....	...	...	...	.....

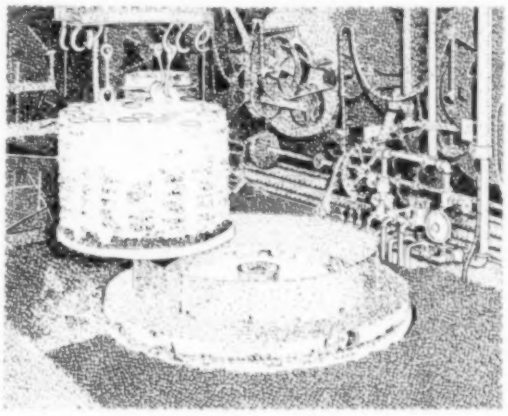
Typical Commercial Gases

Kind of Gas	Constituents of Gas—Per Cent by Volume															
	CO_2	Ill.	O_2	CO	CH_4	C_2H_6	H_2	N_2								
Natural gas																
Mid-Continent	0.8	...	...	...	96.0	...	...	3.2	0.575	0.0440	22.71	....	974	877	22.122	19.919	9.15	...	0.968	1.92	7.26
Ohio	...	...	...	...	80.5	18.2	...	1.3	0.650	0.0498	20.09	....	1,143	1,034	22,966	20,775	10.70	...	1.169	2.16	8.47
Pennsylvania	...	...	...	...	67.6	31.3	...	1.1	0.714	0.0547	18.29	....	1,247	1,131	22,809	20.687	11.66	...	1.302	2.29	9.22
California	0.8	...	...	...	75.1	23.0	...	1.1	0.680	0.0521	19.21	....	1,174	1,063	22,548	20,416	10.99	...	1.219	2.19	8.69
Coal gas																
Horizontal retort	2.1	3.8	0.4	8.7	28.2	2.8	50.5	3.5	0.431	0.0330	30.30	....	613	550	18,575	16,666	5.32	...	0.566	1.240	4.24
Horizontal retort	2.8	4.5	0.6	7.4	34.3	...	41.6	8.8	0.493	0.0377	26.49	....	609	548	16,133	14,517	5.35	...	0.591	1.206	4.32
Vertical retort	3.0	3.1	0.6	7.0	32.8	...	50.4	3.1	0.397	0.0304	32.90	....	569	507	18,718	16,679	4.91	...	0.490	1.222	3.91
By-product coke oven gas.	2.1	3.2	0.4	6.4	30.3	...	53.9	3.7	0.378	0.0289	34.55	....	563	502	19,452	17,344	4.85	...	0.468	1.213	3.87
Water gas																
Carburetted	3.3	10.7	0.7	33.4	10.0	...	38.1	3.8	0.651	0.0498	20.06	....	562	521	11,274	10,452	4.73	...	0.789	0.822	3.78
Carburetted	4.7	10.8	1.1	25.9	14.5	...	33.2	9.8	0.685	0.0525	19.07	....	569	526	10.848	9,964	4.86	...	0.775	0.865	3.94
Uncarburetted	5.0	...	0.5	44.0	2.0	...	44.0	4.5	0.593	0.0454	22.02	....	305	281	6,717	6,189	2.26	...	0.510	0.480	1.83
Pacific Coast oil gas	6.3	4.6	0.4	12.6	26.1	...	45.6	4.4	0.509	0.0390	25.66	....	555	501	14,240	12,855	4.79	...	0.594	1.083	3.83
Producer gas																
Anthracite coal	6.6	0.3	...	25.1	0.3	...	18.7	49.0	0.837	0.0641	15.60	....	149	139	2,325	2,169	1.115	...	0.326	0.199	1.371
Bituminous coal	2.5	0.4	0.3	27.0	2.5	...	12.0	55.3	0.866	0.0663	15.08	....	158	149	2,383	2,247	1.210	...	0.328	0.178	1.509
Blast furnace gas	14.5	...	...	22.8	...	...	5.1	57.6	1.006	0.0770	12.98	....	90	87	1,168	1,129	0.665	...	0.373	0.051	1.101

Notes: *Figure calculated on assumption that substance could exist as gas at 60° F. and 30 in. of mercury.

(a) Liquid
(b) Solid
(c) Contains 0.94% argon by volume, about 0.03% CO_2 and trace of hydrogen.
(d) Purified, dry air contains 20.99% oxygen and 79.01% nitrogen and other inert gases by volume (or 23.20% oxygen and 76.80% nitrogen by weight).

very careful control of combustion. In addition highly developed machinery is required for feeding the wire through the flame, for rewinding the annealed wire, very close control of speeds and infinite speed variations to suit varying degrees of anneal. An experimental unit with a flame 9 ft. long, together with its full complement of machinery, has been under test in laboratory experimentation for some time. It has been so successful that a new burner 27 ft. long is now going into a copper wire plant as the first production unit.



The successful operation of this unit will open another field for similar applications, not only in the copper wire industry but in others as well where rapid and controlled annealing is desired. Once again a new tool is being made available to the metallurgical industry in speeding up operations, simultaneous with a more accurate control of the desired result and with overall lower operating costs.

Convection Heating
revolutionizes furnace design

By Cary H. Stevenson
Lindberg Engineering Co., Chicago, Ill.

IN ATTEMPTING to peer into the future of convection heating I am reminded of the early history of the electric furnace industry. The first electric furnaces were built by fuel furnace engineers, and were simply fuel furnaces with the burners and flues omitted, and elements installed along the sides of the furnace where the burners would have been. As a matter of fact, in the early days more than one attempt was made to change fuel-fired furnaces into electric furnaces by simply putting elements in them.

But as experience accumulated, it was found that this new method of industrial heating had peculiarities of its own; some advantageous, and some otherwise. Wall thicknesses and wall materials were changed. Heating elements were located on other surfaces of the furnace — in some cases, even on the inside surface of doors and covers. New furnace mechanisms were found applicable in the absence of high flame temperatures. Atmospheres of all kinds could be introduced, and this important phase of furnace operation was advanced considerably. Merely the adaptation of a new type of heat-source had changed the design of the entire equipment — details of design which at first would not seem to have any relationship to the heating medium.

In much the same way convection heating is effecting, and in the future will even more drastically effect, the design of furnaces, methods of handling, and atmosphere applications. For example, batch type furnaces with deep bulky loads in containers are in many cases preferable to continuous furnaces where the work is spread thinly on conveyors. This is true because modern convection heating can heat a bale of steel wool as easily as an equivalent amount of steel in the shape of a single plate.

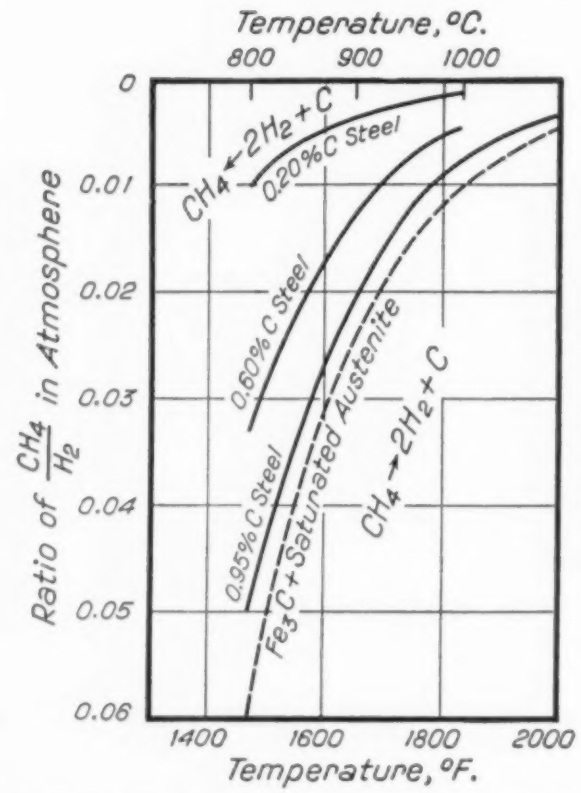
The tendency will be more and more evident to reduce cross sectional area of heating chambers in order to increase velocities. Thought will be given in the loading of convection furnaces to eliminate any detouring of the blast around the work. The complete elimination of radiant heat from the heating source and even its reflection should be expected.

Convection heating involves many atmosphere problems which will have to be solved, particularly in the non-ferrous field, where the temperatures of convection heating fit so well. We no longer have the simple solution of sealing the work in the retort, for fan, ducts, heating medium and work must all be within the enclosure. Muffles in fuel-fired furnaces are practically ruled out, but fortunately radiant tubes will permit gas to be used as a source of heat. I also believe that the furnace engineers are beginning to question that part of their old textbooks which limited the advantages of convection heat to temperatures below 1200° F.

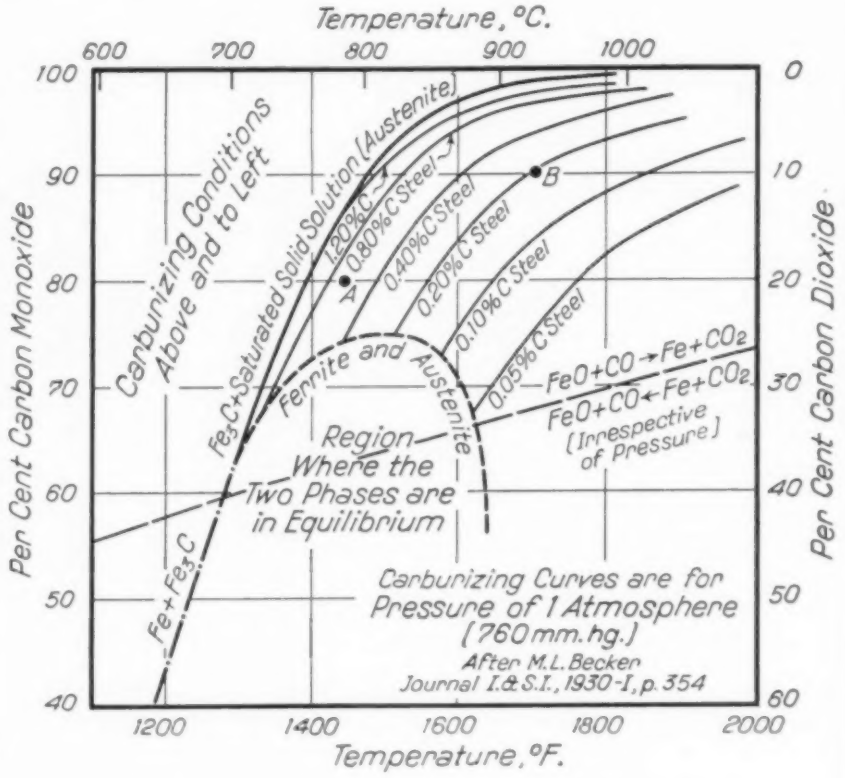
The future of convection heating will therefore be concerned more and more with the development of the structures themselves to obtain the inherent advantages of the method.

Equilibria for Gas-Steel Reactions

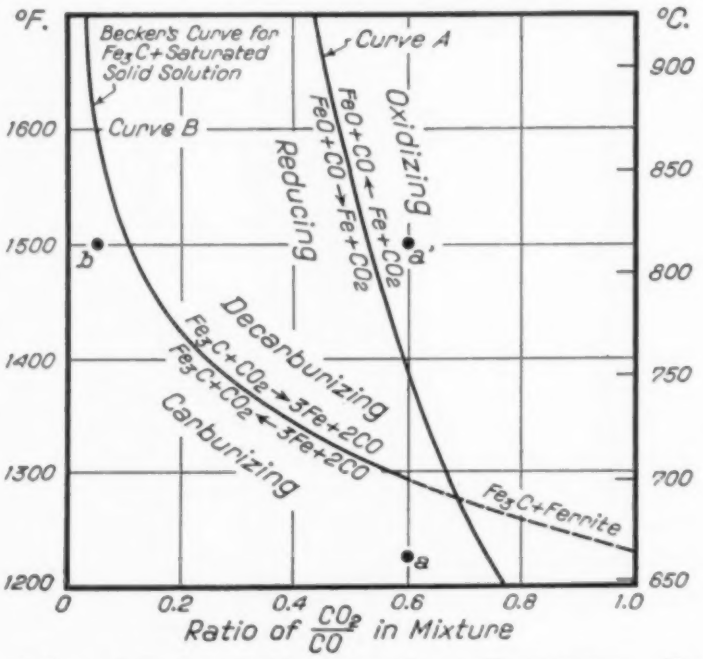
Relation Between Gas Composition, Temperature, and Carbon Content in Steel



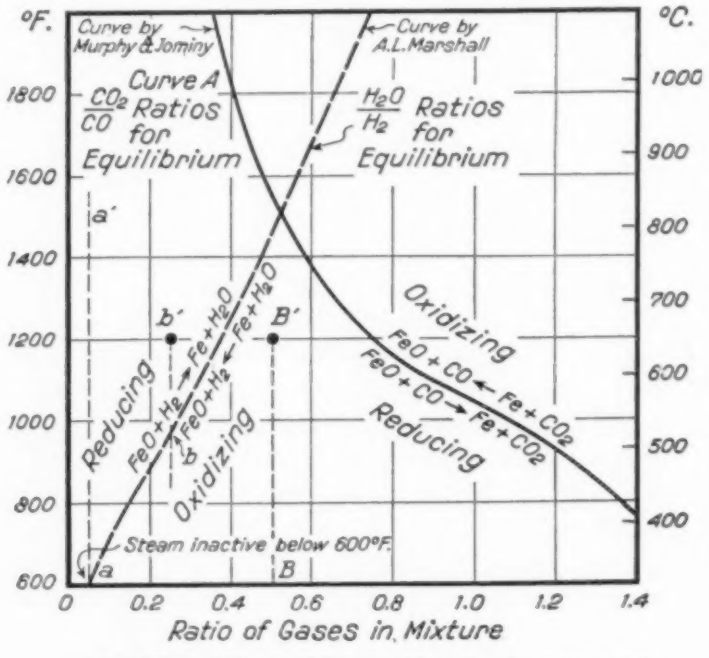
Above Curves, Adapted by Stansel From Sykes' Work, Indicate That Almost Pure H_2 Decarburizes Hot Steel (Conditions Above and Left of Corresponding Curves). Methane breaks down almost completely into carbon and hydrogen, carburizing steel (and depositing excess soot) at conditions below curves



Carburizing Reactions Depend on Carbon in Steel. Thus: 80% CO, 20% CO_2 at 1450° F., (point *A*) will carburize 0.40% C steel and lower, but decarburize 0.80% C steel and higher. However 90% CO, 10% CO_2 at 1700° F., (point *B*) is relatively inert to 0.20% C steels, will carburize lower carbon and decarburize higher carbon steels. Partial pressures, i.e., $CO + CO_2 < 100\%$, raise curves and shift to left



Action of Carbon Oxides Depends on Temperature. For instance, a dried atmosphere containing 6% CO_2 and 10% CO or ratio 0.6 (easily secured by partial combustion of fuel gas) would tend both to reduce and carburize at a 1225° F. anneal (Point *a*), but would both decarburize and oxidize at 1500° F. (Point *a'*). For "bright hardening" the CO_2 must be reduced well below Curve *B* (for instance, 1/10 the CO, as Point *b*, at 1500° F.). The above statements neglect the fact that the pressure of CO + CO_2 is less than 1 atmosphere



Oxidizing Action of Steam May Be Counteracted by 20 Times As Much Hydrogen (Line *a-a'*). Larger proportions of steam may scale the metal during cooling (line *b'-b*). Oxidizing — and decarburizing — propensities of moist gas may likewise be counteracted by carrying excess CO in the mixed carbon oxides present in the furnace atmosphere (for instance, $CO_2 : CO = 0.5$, or line *B-B'*, on the reducing side of curve *A*)

Electric Heating Furnaces

By P. H. Brace
Research Laboratories, Westinghouse Electric & Mfg. Co.
East Pittsburgh, Pa.

DURING 1939 the general trend of electric heating development has followed the lines of the previous year and several important details have been perfected.

There has been a marked trend toward specialization of controlled atmosphere with reference to the material being treated. At least three distinct types of atmosphere, broadly classifiable as "rich", "lean" and "inactive", and based on controlled combustion of hydrocarbons, have been introduced commercially to meet the demand for "bright" heat treating processes. Demand at present is not only that bright surfaces be maintained but that the composition of the exposed material remain unaltered or else be changed in a predictable way.

As new possibilities come into view, new exactions are made. Further advances will come as the kinetics of the gas-metal reactions involved are better understood. Refinement of control systems seems likely to play an important part in making the results of research available to the manufacturing engineer.

Back of all this are specialized systems for producing the desired atmospheres. Electric heat plays an important part in the operation of many of these.

There has been considerable experimental activity in electric furnace brazing in the non-ferrous field, alloys rather than copper being used as solder. Particularly accurate temperatures and proper selection of atmospheres are important. Although this is a more difficult art than that of copper-brazing steel assemblies, increasing use may be expected, not only in the joining of non-ferrous parts but in other cases where the high temperatures necessary for copper brazing are detrimental.

Bright hardening followed by bright tempering is coming into use, and the pleasing results obtainable with materials that can be gas-quenched lead one to expect almost a revolution in the heat treatment of such things as tools and dies.

Considerable interest attaches to vertical continuous furnaces for the bright annealing of strip steel. In one of these recently put into operation a thermal cycle is applied that would require a horizontal furnace more than 200 ft. long! The floor space required is a small fraction of that necessary for the equivalent horizontal furnace and the mechanical and heat distribution problems seem to have been solved in a very satisfactory way. Furnaces of this type appear to offer very interesting possibilities where tonnage must be handled in special thermal cycles of not too great duration.

Resistor materials, both metallic and non-metallic, are gradually being improved both as to life and permissible operating temperatures. Further invasion of previously inaccessible temperature ranges seems likely. In this direction ceramic-coated, refractory-metal heating elements offer interesting possibilities, particularly for smaller furnaces where temperatures above 2200° F. in oxidizing atmospheres are desired.

Some urge continues for electric furnaces for ceramic work, but hopes along this line are clouded by high power costs.

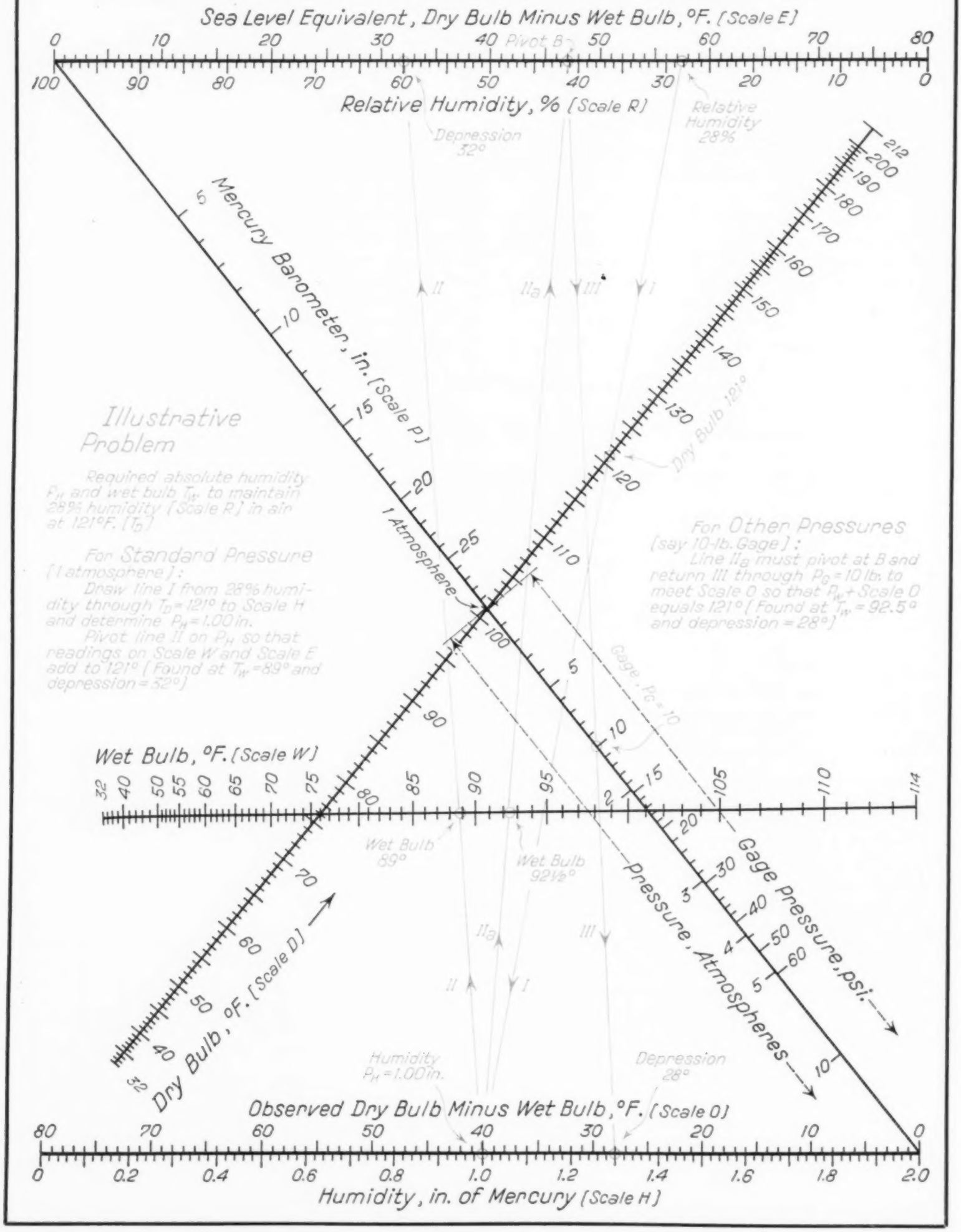
Inductive heating has been applied to the problem of localized heat treatment on a larger scale than heretofore. A recent development uses inductor systems of rather special design comprising special magnetic materials, and operates at the moderate frequencies obtainable from motor-generator sets. By this means quite remarkable amounts of power can be applied locally and some previously impracticable heat treatments have been accomplished commercially. Important developments along this line are to be expected as designers of mass production equipment become more familiar with the ability of inductive heating to completely mechanize and localize a heat treatment, and as economics make such processes profitable.

The requirements of radio broadcasting have brought about the development of very reliable sources of power in the higher frequency range. The art of making and applying thermionic tubes and related apparatus has so far developed that it is now relatively easy to provide tens or even hundreds of kilowatts at frequencies of the order of 100,000 cycles per second under push-button control and readily adaptable to metallurgical requirements.

Such frequencies make it possible to heat small parts with great rapidity — a $\frac{3}{16}$-in. steel bar to 2000° F. in 8 sec., for example. There appears to be considerable room for wider application of these higher frequencies where rapid, intense or highly localized heating is required not only for hardening but also for welding, brazing, upsetting and forging operations where relatively small objects are dealt

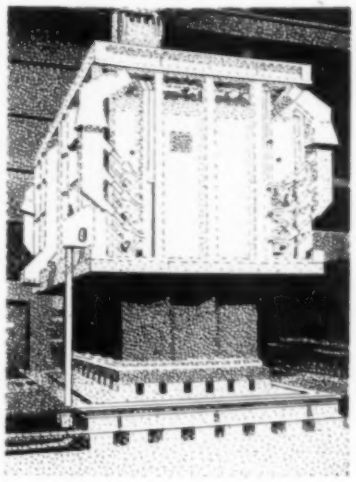
Psychrometric Chart, High Range

By Donald B. Brooks; National Bureau of Standards. Publication M-146


Sea Level Equivalent, Dry Bulb Minus Wet Bulb, °F. [Scale E]
0 10 20 30 40 Pivot B 50 60 70 80
100 90 80 70 60 50 40 30 20 10 0
Relative Humidity, % [Scale R]
Depression 32°
Relative Humidity 28%
Mercury Barometer, in. [Scale P]
15 16 17 18 19 20 21 22 23 24 25
1 Atmosphere
II
IIa
III
I
212 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 32
Dry Bulb 121°
Illustrative Problem
Required absolute humidity P_H and wet bulb T_W to maintain 28% humidity [Scale R] in air at 121°F. [T_D]
For Standard Pressure [1 atmosphere]:
Draw line I from 28% humidity through T_D = 121° to Scale H and determine P_H = 1.00 in.
Pivot line II on P_H so that readings on Scale W and Scale E add to 121° [Found at T_W = 89° and depression = 32°]
For Other Pressures [say 10-lb. Gage]:
Line IIa must pivot at B and return III through P_G = 10 lbs. to meet Scale O so that P_H + Scale O equals 121° [Found at T_W = 92.5° and depression = 28°]
Gage, P_G = 10
Wet Bulb, °F. [Scale W]
32 40 50 55 60 65 70 75 80 85 90 95 100 105 110 114
Wet Bulb 89°
Wet Bulb 92½°
Dry Bulb, °F. [Scale D]
32 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 212
Pressure, Atmospheres
1 2 3 4 5 10 15 20 25
Gage Pressure, psi.
5 10 15 20 30 40 50 60 100
Humidity P_H = 1.00 in.
Depression 28°
Observed Dry Bulb Minus Wet Bulb, °F. [Scale O]
80 70 60 50 40 30 20 10 0
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Humidity, in. of Mercury [Scale H]

Metal Progress, 1939 Reference Issue, Page 510

with. Heating equipment of this type is likely to appear in the guise of machine tools in mass production lines. Here again the immediate rate of progress will hinge largely on the ingenuity of metallurgists, designers and production men. First cost of the electrical equipment involved is not out of line, considering all things, but lower prices will no doubt follow wider use and standardization of the requirements.



To sum up, it appears that most of the advances in the electric heating art, in the near future, will result from bold application in mass production industries of the improved agencies now available for controlling electrical energy and transforming it into heat at desired points. It also seems likely that the design of equipment for manufacturing metal products (and the design of the products themselves) will be altered in significant ways by the application of mechanized electric heating to the task of lowering costs and, possibly more important, accomplishing new things.

Potent new tools are in the hands of the man who once toiled beneath the spreading chestnut tree!

Furnaces for Annealing Strip-Sheet

By James J. Bowden
Chief Metallurgist, Cleveland District
Republic Steel Corp.

IN A BRIEF COMMENT under the same title in last October's METAL PROGRESS, the writer indicated the relative merits of continuous annealing in a tunnel furnace and discontinuous annealing in boxes. The conclusions stated then still are true. Most of the sheet made in continuous mills is annealed in boxes. Actual heating and cooling cycles are controlled in the last analysis by the demands of the customer, but are so influenced by the prior history of the steel in the openhearth shop, reheating furnaces, hot mills and cold mills that it is difficult to write anything very specific about them.

Since the physical and metallurgical changes in steel are speeded up as the temperature increases, we like to use as high a furnace temperature as possible and still avoid conditions that will produce detrimental properties, for in this way the greatest economy is obtained.

The heat treating plant represents a large investment and must produce large tonnages so we design our furnaces to anneal as large a charge as can be handled in a practical manner and still get the desired quality. In any event, they must be big enough in floor area to take the largest sheet on our list, which is approximately 8x20 ft.

Such essential requirements of production are met by two different types of equipment. One is merely an improved stationary furnace and the load is moved in and out. The other has a stationary base carrying the load and the furnace is moved on and off. Either type may be heated by electric resistors, radiant tubes or open flames. In either type, the pile of sheets is contained in a tight box, which is in reality a muffle of relatively thin metal, and which also encloses a prepared gas, slightly reducing in nature, to protect the sheets from oxidation. The two types of equipment are about equal in over-all economy, as is proved by the fact that some of the new wide strip mills use stationary furnaces while others use movable furnaces.

Republic's new 98-in. strip mill in Cleveland uses large stationary furnaces, and a special charging machine for handling the box-loads. They are fired with open gas flames and the protective boxes scale and warp after continuous use.

In both types of equipment, it is ordinarily rather difficult to get a nearly uniform temperature from the top of the pile to the bottom, which makes it necessary to soak the charge for a number of hours to promote the drifting together of these two temperatures. This feature (difference between top and bottom temperature) is one that is challenged in many ways and in the stationary type used by us, a plan of raising the pile up from the bottom to allow the circulation of the heating gases has helped considerably.

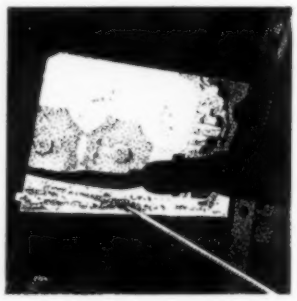
Uniform temperature throughout the pile is of greatest importance. Assuming that the sheets are to be annealed at 1275° F., we cannot call the job done until all regions of the steel mass reach that heat *(Continued on page 516)*

Atmosphere Furnaces
and atmosphere producers

By Matthew H. Mawhinney
Consulting Engineer
Salem, Ohio

OUTSTANDING new developments in the past year in the field of atmosphere furnaces for metal heating are absent, but considerable progress was made in their wider application to all kinds of finished products.

Notable examples of this progress are the many new furnaces for the annealing of wire, tubes, and strip, bright hardening and brazing. An outstanding application has been the successful annealing of stainless steel in strands in an electric furnace, using cracked ammonia gas for atmosphere.



The non-ferrous metal industry has also kept pace in the further development of bright annealing equipment, with the installation of open furnaces for copper, and of bright annealing furnaces with separate generators for this and other products.

Probably the most important progress made in the year has been in the methods of producing protective gases and in the study of their action on the various steels and other metals. These still remain the two most important problems to be solved.

The necessity for removing carbon dioxide from cracked hydrocarbon gases in addition to thorough drying is now generally recognized. After several troublesome installations of "tetramine" equipment for this purpose, a method utilizing mono-ethanolamine has now been developed which promises success. Gases high in carbon monoxide and made from charcoal have been further developed and are attracting more attention as protective atmospheres, particularly where decarburization is to be prevented.

Forecasting the future in this field, it seems logical to expect that the coming year will again be devoted to a better understanding and better use of present methods rather than the development of entirely new methods. The value of present methods has been only partly realized, and the problems of scale formation and decarburization are still increasing in importance at a rate more rapid than the adoption of methods of preventing them which are now available.

In the field of open fired furnaces, development can be expected in the control of atmospheres in soaking pits and in high temperature furnaces for process heating, such as billet heating for rolling and forming where a great deal of trouble is yet experienced. Poor surface conditions and loss of carbon in this class of equipment constitute one of the most serious of all metal problems, but exact solutions such as are now possible in the finishing departments have so far been prevented by the necessity of heating to high temperatures and the bulky nature of the metal at this stage. A considerable amount of investigation is going on with paints, compounds, and materials to be introduced into the furnace to reduce scaling and decarburization, and perhaps some discovery along these lines will result.

In the finishing processes, where successful methods are already available, the developments to be expected include simpler machines for preparing the atmospheres. Also it is to be hoped that knowledge will become more widespread of the applications of the gas best suited for specific conditions, and in the technique of using the gases so as to insure more consistent results with less necessity for highly skilled operators.

Tool Hardening Furnaces

By J. A. Comstock
Consulting Metallurgist
Surface Combustion Corp., Toledo, Ohio

NO ONE has as yet discovered the secret of burning fuel to produce simultaneously heat and metallurgically neutral products of combustion. (The exception to this is in the heating of nickel and copper and their alloys, such as monel metal.) This means that, to obtain maximum freedom from scaling and decarburization, it is necessary to separate the work chamber from the combustion chamber of a fuel-fired furnace.

Gas-fired muffles with controlled atmospheres are in general use today as economical tool hardening furnaces producing highest quality work. Metallic alloy muffles are practical up to 1850° F., while refractory muffles are available in two or more grades covering the

entire temperature range up to 2400° F. Muffle cost is a very small percentage of the total cost of tool hardening, where modern requirements for tool surface have to be met.

Improvements during the past year in muffle furnaces for tool hardening have come mostly from the adoption of methods of atmosphere control developed in connection with large tonnage furnaces for mill heating operations. Instead of the atmosphere generator unit being built as a separate piece of apparatus, it is desirable to build it integral with the tool hardening furnaces. This type of construction lends itself to the supply of a hot atmosphere to the work chamber or muffle, thus preventing any unbalance by cooling and reheating (the atmosphere having been balanced at the work chamber temperature in the integral generator).

The importance of a balanced gas is obvious from the equilibrium constants of the various gas systems at different temperature levels

$$\frac{CO_2}{(CO)^2} = K_1 \qquad \frac{H_2O}{H_2} = K_2 \qquad \frac{CO \times H_2O}{CO_2 \times H_2} = K_3.$$

Since gases are not heated by radiation (especially if low in CO_2 and H_2O) a cold gas entering a muffle will be heated by convection and conduction from the work itself, thus causing gaseous reactions to take place on the surface of the work with consequent damage to it. In many cases also the metal is a catalyst, causing these reactions to approach equilibrium on the surface of the work. Atomic reactions at the very surface must be controlled as well as the molecular reactions, and unfortunately chemical analysis offers very little help with respect to the former. It is now well known that the analysis of the furnace atmosphere does not represent the conditions existing at the surface of the work.

Maintenance of a controlled atmosphere requires a regulated rate of flow as well as pressure. Rate of flow is extremely important in short heating cycles in bringing the film of gas on the surface of the work into equilibrium with the prepared atmosphere which is in equilibrium with the work at temperature. A muffle of one square foot cross section may require for a given balanced atmosphere a flow of 100 to 150 cu.ft. per hr. There appears to be a relationship between the rate of flow required and the rate of heating of the work.

A positive muffle pressure is required to prevent infiltration of outside gas through cracks and door openings. When it is seen that less than 0.5% CO_2 is allowable in connection with 34.0% CO for equilibrium with a 1% carbon steel at 2200° F., it is apparent that infiltration or pick-up of oxidizing gases must be held to a minimum.

An atmosphere made from fuel gas and air in a built-in reaction tube or generator can be maintained in a muffle in a balanced condition as regards the water gas reaction $\left[\frac{CO_2 \times H_2}{CO \times H_2O} = K_3\right]$ although the percentage of water vapor and CO_2 may be relatively high and oxidize and decarburize certain analyses (such as molybdenum steels). In order to eliminate the water gas reaction entirely, so as to adjust the ratio of CO to CO_2 for zero decarburization, a gas having low hydrogen and water vapor with the CO and CO_2 in equilibrium for the desired temperature can be obtained by passing air over "charcoke". The raw material for this atmosphere is charcoal which is coked in process as it passes through the generator, the volatile content of the charcoal being wasted through a vent in the upper zone of the retort and carrying with it the water and other hydrogen-containing gases.

Protective atmospheres have boomed continuous automatic furnaces by eliminating the necessity for individual handling of the work by skilled operators. Atmospheres that are non-decarburizing as well as non-scaling have opened up the field for continuous hardening furnaces of all types, including tool hardening. Equally important are continuous hardening furnaces for various parts which must be made to withstand wear, abrasion, or fatigue.

So much for muffle type furnaces. But atmospheres in semi-muffle furnaces must be regulated, as far as products of combustion are concerned, for best results regarding scaling and decarburization. There is a better appreciation of how to effect this control, especially as to the elimination of decarburization. If the furnace is properly designed to allow the hot products of combustion to become stabilized before coming in contact with the work, and a slight positive pressure maintained in the furnace (regardless of turndown on the burners) to prevent infiltration of outside air, then by means of proportional mixers the desired furnace gas composition can be maintained.

Very laudable work has proved the advantages of maintaining a definite excess of oxygen in the furnace atmosphere to eliminate decarburization, while at the same time scaling is kept at a low level. Direct fired furnaces are apt to

be quite variable in their atmosphere, due to their design being an old type in common use before atmosphere control became popular.

On the whole, the status of the art pertaining to tool hardening furnaces seems to be a healthy one.

Salt Baths

By Harrison I. Dixon
The Electro Alloys Co., Elyria, Ohio

IN A CONSTANTLY CHANGING FIELD of economic warfare, manufacturers and producers of heat treated metal parts have been revamping their equipment to include modern salt bath furnaces capable of producing carbon "cases" from one to 60 thousandths deep, light nitrogen "cases", conventional cyanide "cases", and for annealing and hardening operations without decarburization. The introduction of economical, stable compounds capable of withstanding temperatures of 250 to 2330° F. without excessive drag-out losses, coupled with modern, pyrometrically controlled furnaces and salt containers, is producing a situation where a variety of machine parts may be so treated, capable of withstanding the high service stresses encountered in parts ranging in size from thin typewriter levers to thick transmission gears. Heat treating costs are being reduced due to higher rates of production, shorter heating time cycles, and better life of salts and containers. Better combustion and insulation of furnaces have helped reduce fuel costs. The industrial hazards encountered a few years ago have practically disappeared.

Salts are definitely superior to other liquid heating mediums for certain operations, due to their high thermal conductivity, cleanliness, prevention of decarburization, minimizing of distortion, cracking, pitting, and prevention of scaling or oxidation. A salt bath transfers heat rapidly from a heated liquid to a cold solid, compared to the slower method of transferring heat units from a heated gas to a cold solid. Compared to lead baths, there is no necessity to hold work under the bath surface; cleaning costs are less, and higher temperatures are possible.

Modern salt baths are divided into four temperature ranges:

1. Tempering: 300 to 1200° F.
2. Annealing, nitriding, hardening, carburizing: 1100 to 1700° F.
3. Annealing and hardening stainless iron and steel: 1600 to 2000° F.
4. Hardening high speed steel: 2100 to 2340° F.

For low temperature work, mixtures of nitrates and nitrites of sodium and potassium are commonly used. For heat treatment of aluminum alloys, nitrate salts in a range of 900 to 1000° F. are used. Pressed steel or cast steel containers are satisfactory for this range.

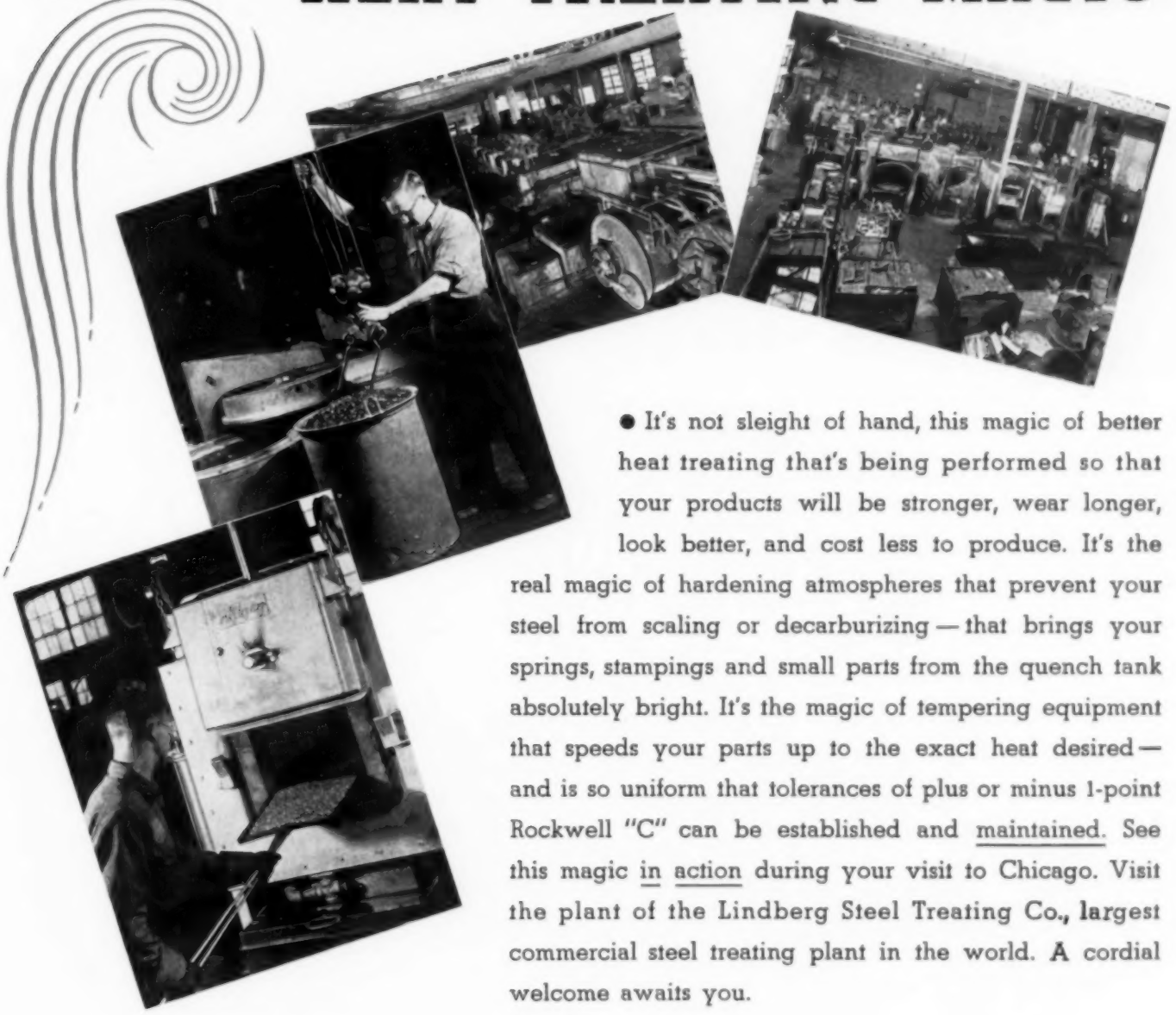
For medium temperatures, mixtures of the chlorides of potassium and sodium are common, plus a borax rectifier to prevent decarburization. Activated carbon is often used as a cover, to form an insulating blanket of scum, to reduce heat losses and prevent decarburization. In this range, pressed or cast steel containers ordinarily give at least 500 hr. service. Nickel-chromium alloy containers, properly designed and cast according to modern foundry practice and inspection, can be expected to give from 1500 to 8000 hr. service. Many modern furnaces are designed for top burner firing in order to melt the cold salt from the top surface down, thus preventing unequal expansion stresses on the container. Salt volume should be sufficient to heat a cold charge up to the bath temperature without excessive temperature drop in the bath; ordinarily a ratio of approximately 3 to 4 lb. of salt to 1 lb. of work is considered good practice, although a large volume of small pieces would require more salt than a small number of larger pieces of the same weight. Many furnaces are now designed for continuous mechanical operation, where the work is placed on a fixture, immersed and moved through the bath, emerging ready for quenching on a definite time cycle. This type of operation is adapted to both round and rectangular pots or containers.

The use of barium salt

(Continued on page 518)

LINDBERG

HEAT TREATING MAGIC



● It's not sleight of hand, this magic of better heat treating that's being performed so that your products will be stronger, wear longer, look better, and cost less to produce. It's the real magic of hardening atmospheres that prevent your steel from scaling or decarburizing — that brings your springs, stampings and small parts from the quench tank absolutely bright. It's the magic of tempering equipment that speeds your parts up to the exact heat desired — and is so uniform that tolerances of plus or minus 1-point Rockwell "C" can be established and maintained. See this magic in action during your visit to Chicago. Visit the plant of the Lindberg Steel Treating Co., largest commercial steel treating plant in the world. A cordial welcome awaits you.

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Bright Anneal

(Continued from page 511)

and stay there awhile. To save time we have a heat source as far above 1275° F. as we can — the limit is that temperature which will cause the edges of the sheets to stick together. "Stickers" are the largest source of loss in wide strip annealing production, and a considerable portion of a pile can easily be ruined merely by over-firing so that the outer edges stick.

The difference between the temperature of the heat source as compared with the temperature that is desired in the pack is referred to as the temperature gradient, and the larger the gradient the faster the anneal, but unfortunately the greater the tendency to stickers, which therefore becomes the limiting factor.

The next great source of stickers is at the bottom of the pile. Even with the best circulation of flames, the bottom center of the pile always heats more slowly; if it is within 40° of the top, we usually think we are doing a good job. The reason why stickers occur at the bottom is, I think, due to the expansive forces of temperature. A sheet near the top of the pile, if it is hotter than the one below, can easily expand because it is not weighted down. At the bottom, however, the inevitable delayed and differential expansion is between sheets heavily loaded, and they "wring" together just as smooth gages do.

A logical improvement is now emerging from the laboratory stage — namely to have a bath of liquid salt or lead, heated by submerged, gas-fired radiators, in the bottom of the furnace, and set the box-load of sheets down into this bath to a depth sufficient to insure good heat conduction from the liquid heating medium.

The bottom of such a pile of sheets naturally will heat up much more quickly due to the proximity to the heating medium. In fact, in the early stages of the cycle, the bottom temperature is as much as 250° F. hotter than the top, but as the cycle goes on to completion, the liquid heating medium and the top and bottom temperatures approach to within 10° of each other.

In this manner, the temperature gradient can be kept very much lower than is the case in the older conventional types of annealing equipment. A lower head of heat will heat the upper portions of the pile at a good rate, it being no longer necessary to drive the heat through the pile to the cold bottom. In two main ways bottom stickers and edge stickers will be sharply reduced, to say nothing of a general improvement in the uniformity of temperature through the pile.

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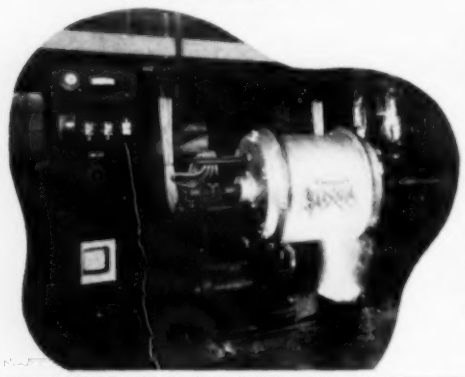

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For cold melting or duplexing.

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THE MONMOUTH PRODUCTS COMPANY, Cleveland, Ohio, have more than doubled their carburizing capacity, and improved the physical qualities, of tie rod ball studs and king pins with the installation of a Hevi Duty Vertical Retort Carburizer. With their former method of pack carburizing, only two charges of approximately 2,000 parts each could be carburized in a day. In the Hevi Duty Carburizer, three loads of 3,000 parts each are carburized in the normal daily production with no increase in floor space.

Send for Bulletin HD 937 — it describes the Vertical Retort Carburizing Furnace.

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Salt Baths

(Continued from page 514) compounds in the treatment of stainless iron or steel, or hardening of high speed steel, has necessitated the use of 28% chromium-iron containers. Chromium-nickel alloys are not serviceable, and cast steel will not stand the high temperatures. The use of the high frequency induction type of heating furnace has been a big factor in strengthening the position held by salts for high temperature ranges. These installations have been well described in previous articles in this magazine. Bath electrodes, pyrometer tubes and salt containers are made of 28% chromium-iron alloy, except where the containers are refractory-lined steel pots. Life of one to six months at temperatures of 2100 to 2330° F. is being obtained with the alloy pot. Daily bailing out of sludge is necessary; this forms from scale and impurities on the steel. Approximately ½% daily additions of rectifiers are usually made to remove carbonates, formed slowly in the molten salt, which are decarburizing.

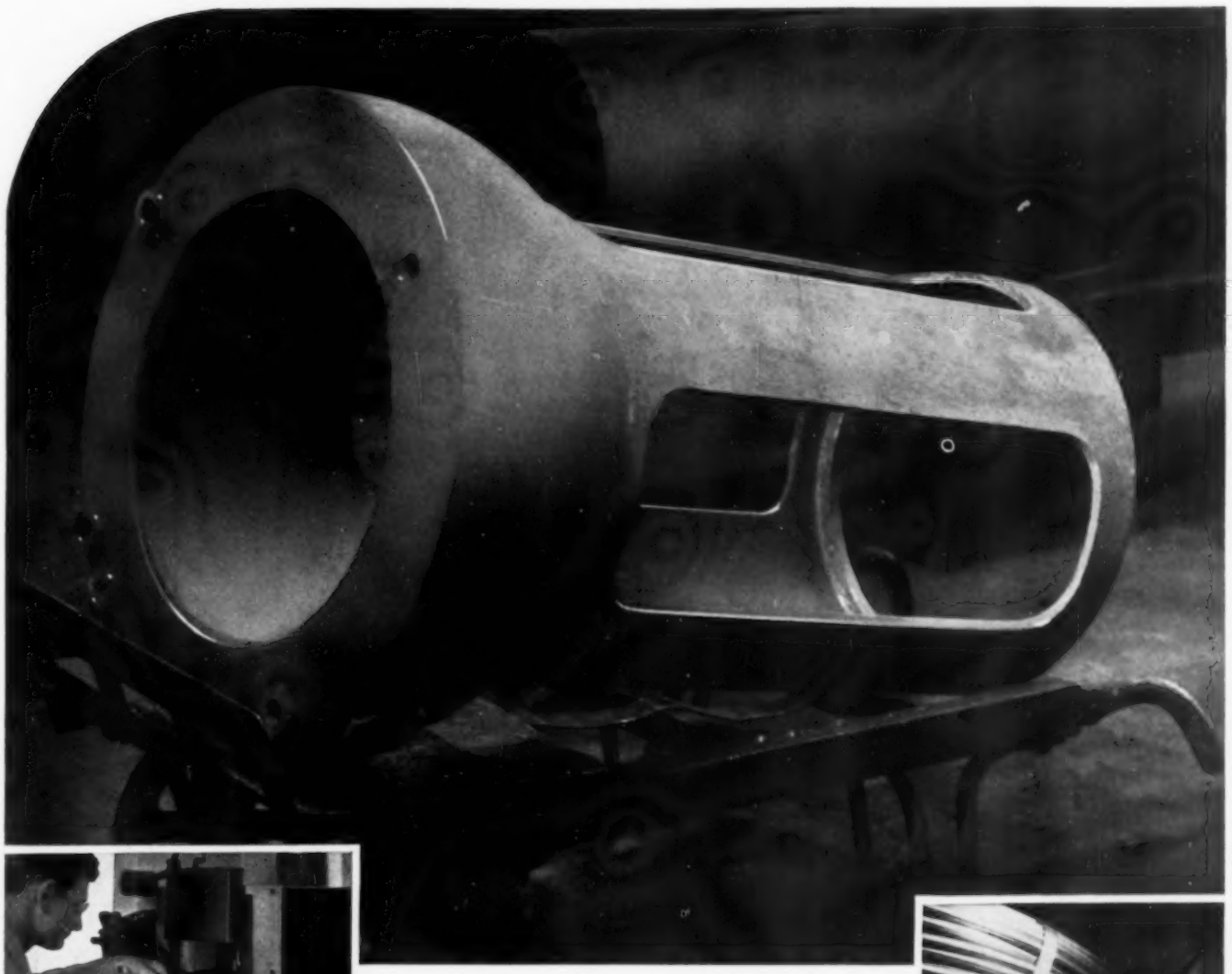
Many manufacturers of high speed tools are adding a final nitride "case", 0.001 to 0.002 in. thick, after the usual hardening and tempering operations, by immersing tools in a special bath held at 1000 to 1100° F. for periods of 10 min. to 1 hr. This additional treatment increases the tool life between grinds up to 300%, when cutting non-ferrous materials at relatively high speeds. Low volatile, clean, thin, liquid transparent salts are also being used to cover lead pots, instead of charcoal or lead pot carbon.

Salt manufacturers are now producing stabilized compounds, so that the addition of a second salt to a "base" salt bath will increase case depth on work requiring greater depth than that obtained from the "base" salt. If a lighter case is necessary for some work, the original salt may be used in the same container, without bailing out entire contents. Simple test methods are available for daily testing the "casing" strength of baths, in the form of indicator capsules, or by determining chemically the relative percentage of "casing" reagent. These prevent waste by over-addition of fresh salt to the bath, or under-casing of work.

The improvement, standardization and economy of salts, coupled with modern furnace and container design, are capable of producing light or heavy cases in relatively short time intervals, and at low cost.

CASTINGS *FOR HOT JOBS*

We make good alloy castings that stand up well at high temperatures. They also weld readily and machine right easily. They vigorously resist oxidation, abrasion and sulfurous atmospheres. Used for furnace parts, retorts, boxes and pots, for example. Light cross-sections and economical heat-hour-cost. . . . Hoskins Manufacturing Co., Detroit, Michigan.



Hoskins electric furnaces are made in a large range of sizes, to fit widely varied needs.

Our casting metal is melted in high frequency induction furnaces, which assure clean castings and extremely close control of composition. Let us quote or give you some design suggestions.

We often save the customer money by showing how castings may be made lighter, with no sacrifice in performance.

(Right) Chromel alloys can be had in hot and cold rolled form, for mechanical uses, demanding heat-resisting properties.

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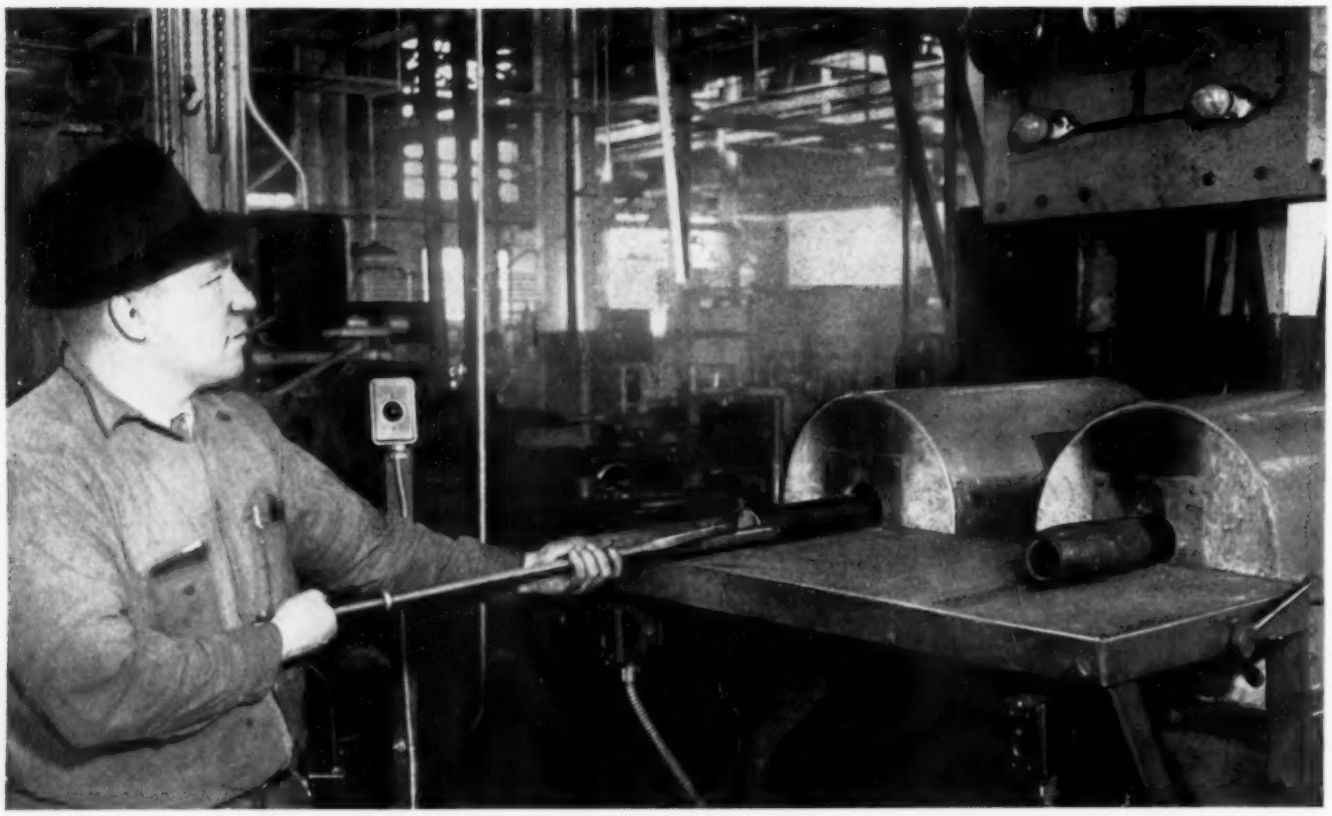

Ajax-Northrup Induction Furnace Heating Steel Bars for 3 Inch Shells—This Ajax-Northrup Furnace in the Artillery Division of Frankford Arsenal is used to heat bars of steel ready for producing two 3 inch shells from each bar. In the left-hand furnace is a bar that has been heated for forging, while in the foreground is a bar that has already been shaped on one end.

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Ajax Electric Furnace Corporation
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Ajax Electric Co., Inc.
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AJ-21

HEAT & CORROSION RESISTANT METALS

METAL PROGRESS OCTOBER, 1939

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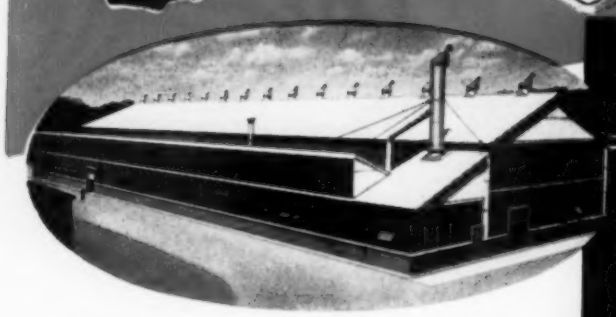

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Heat Resisting and Corrosion Resisting Metals

Marketing of Stainless Steel

By J. M. Schlendorf
Asst. Vice-President in Charge of Sales
Republic Steel Corp.

A SURVEY of production facilities, market problems and potential markets indicates that stainless steel is continually forging ahead. The product is no longer considered a jewelry store item but is rapidly attaining a definite, recognized place in the steel industry. It is becoming more of a "tonnage" than a "poundage" product.

Because of the unlimited uses to which the metal can be put and its growing acceptance for applications where it has already been tried and proven, stainless steel has not suffered the reverses encountered throughout the past year by the so-called common steel products. Steel manufacturers, recognizing a steadily growing demand for the material, have increased facilities, improved the standard of the output, expanded old and exploited new markets. In sales solicitations they have found ready appreciation and receptiveness, largely as a result of widespread knowledge of its satisfactory performance in many directions. Like all products, it must and should earn its own way.

Stainless, to date, has naturally attained more interest in selected fields. Brief comments pertinent to such uses follow.

Aircraft — The high melting point of stainless steel and its great resistance to oxidation have given the aircraft designer a new material with which to combat the dangerous, ever-present fire hazard. The one drawback to designers is a fairly low proportional limit, but [as shown by Russell Franks on page 548] a low temperature heat treatment will raise this to a figure giving weight-strength properties superior to competitive alloys. Flatness in high tensile, cold-worked stainless in thin sheet and strip has been one of the major problems confronting producers, but new equipment recently installed in our plants will overcome this difficulty.

Architecture — Extensive use of stainless at the two World's Fairs indicates that architects and designers believe it not only to be the outstanding metal with which to obtain rich and vigorous decorative effects, but, following the theme of one fair, is also destined to be the "Metal of Tomorrow".

Automotive — Tonnage continues to increase. Steering wheels with stainless steel spokes are now fairly well standardized. Radio antennae may eventually mean excellent tonnage. Automotive applications, especially for trim, continue to represent the largest industrial outlet for stainless.

Beverages — Soft drink manufacturers have long used stainless both in processing equipment and in drums and barrels for shipping syrups. Recently, too, the wine industry is utilizing it for the rapid aging of wine.

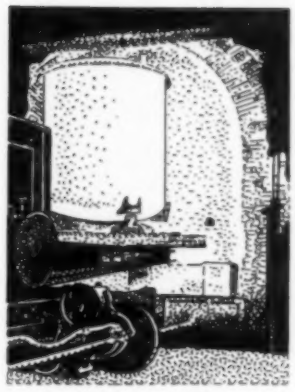
Relative Corrodibility of Some Common Metals and Alloys

Compiled 1933 by Jerome Strauss, Vanadium Corp. of America

Class of Material	Nominal Composition							Atmospheres		Water						Oxidation Resistance Max. Safe Temp. °F.			Fruit, Vegetable Juices	Dairy Products	Other Food Products	Acids Moderate Concentration 5-15%					Alkalies		Salt Solutions Medium Concentration			Hot Sulphite Liquor	Dye Liquor	Refinery Crudes Below 400°F.	
	Carbon	Chromium	Nickel	Silicon	Copper			Sea Shore	Industrial	Domestic	Mine	Sea	Saline with H_2S	Brackish with Mcl	Wet Steam	Oxidizing Gases	Reducing Fuel Gas	Sulphur Rich Gas				HCl	H_2SO_4	HNO_3	Acetic	Phosphoric	1 to 20% Sol.	Fused	NH_4Cl	$MgCl_2$	$MgSO_4$			Sweet	Sour
Ingot iron or wrought iron	0.03				0.08			P	P	P	P	PF	P	F	F				P	P	P	P	P	P	P	P	E		P	F	F	P		F	P
Low C steel	0.10				0.08			P	P	P	P	F	P	F	F				P	P	P	P	P	F	P	P	E		P	F	F	P		F	P
Low C copper steel	0.10				0.25			F	G	P	F	F	P	F	FG				P	P	P	P	P	F	P	P	G		P	F	F	P		F	P
Hot galvanized iron & steel								G	G	F	F	G	F	F					P	P	P	P	P	P	P	P	F		P	P	PF	P		F	P
Calorized iron & steel								G	G	P	P	P				1650	1650	1650	P	P	P	P	P	P	P	P	P		P	P	P	P	F	FG	FG
Gray cast iron	2.8 graphite, 0.7 combined carbon							F	G	F	F	F							P	P	P	P	P	P	P	P	E	F	P	P	P	P	P	F	
High silicon iron	0.60			14.25				E	E	E	G	E							Gt			F	E	E	G	G	E		G	G	G	P	P	F	
Nickel cast iron	3.30		3.50	1.50				F	G	P	P	F										F	E	E	G	G	E	FG				P	P	F	
Chromium cast iron	2.50	25.00		2.00				G	G	G	G	FG				1800	1800	1800																	
Ni-Cr-Cu cast iron	3.00	2.00	14.00	1.50	6.00			G	G	G	G	G	F	F	G	1200	1200	1200	F			F	F	P	G	G	G	G	F	F	F	F	F	G	G
Nickel steel : Low Ni	0.18		3.00					F	G	F	P	F							P	P		P	P	P	P	G	E	G	F	E	E			
High Ni	0.30		28.00					G	G	G	FG	E							F			F	G	P	P	P	E	G	F	E	E			
Chromium steels : 5% Cr	0.15	5.00						F	F	F	P	P	P	P	F	1200	1200	1200	P			P	P	P	P	P	G		P	P	F	P	P	G	G
12% Cr	.10 max.	12.00						G	G	G	F	F		F	G	1400	1400	1400	G		G	P	P	G	G	F‡	E		G	G	G	P	F	E	E
17% Cr	.10 max.	17.00						G	G	G	G	G		G	G	1600	1600	1500	G	G	G	P	P	G	E‡	P	E		G	G	G	F	F	E	E
17% Cr, 4% Mo	.10 max.	17.00				Mo 4.0		G	G																										
27% Cr	.50 max.	27.00						G	G	E	G	G		G	E	1900	1900	1800	E	G	E	P	P	E	F	G	G		E	E	E	GE	PG		
Silcrome, (8% Cr, 3% Si)	0.45	8.25		3.50				G	G	F	F	F	F	F	F		1500		F			P	P	E	G	E	E		E	E	E	G	G	E	E
Stellite	3.0 max.	30.00				Co 55.0	W 15.0	E	E	E	E	E	E	G	E	2000	2000		E	E	E	F	G	E	G	E	E		E	E	E	G	P	G	E
Cr-Ni steels : 8-20	0.20	8.00	20.00					G	G	G	G	G				1600	1600					P	G	F	G	G	G	G	E	E	E	GE		E	E
18-8, 4% Mo	0.15	18.00	8.00			Mo 4.0		E	G	E	G	G	E	E	E							P	F	G	G	G	E	G	E	E	E	GE	F	E	E
18-8	0.10	18.00	8.00					E	G	E	G	G	E	G	E	1550	1550	{300 to 1300	G	E	E	P	F	G	G	F	G	FG	E	E		G		E	E
18-12	0.10	18.00	12.00					E	G	E	G	G										P	F	G	G	F	G					P			
18-35	.50 max.	18.00	35.00	1.00				E	G	E	FG	G				1900	1900	1900	G			P	P	G	P	F	G	G	E	E	E	GE	G	E	
25-12	.25 max.	25.00	12.00					E	G	E	G	G	E	G	E	2100			G	E	E	P	P	G	G	F	G	G	E	E	E	E	G	E	
26-24	.15 max.	26.00	24.00	3.00				E	G	E	G	G	E	G	E	2100	2000		G	E	E	P	F	G	G	G	G	E	E						
Commercially pure Ni			99.20					E	G	E	G	E	G			1300	2000	P	G	GE	GE	G	G	P	G	G	E	E			G	P	G	F	
Nickel alloys : Monel metal	0.15		67.50	0.50	28.50	Mn 1.50		E	G	E	PE	E	G		E	900	2000	P	G	FE	FG	FG	G	P	G	G	E	G	E		G	P			
Nichrome, 60-15	0.12	15.00	60.00					G	G	E	G	G				1475 to 2100		P	G			F	F	F	G	G	G								
Inconel, 14% Cr		14.00	80.00			Fe 6.0		G	G		G	G				2000	2000		E	E	E														
80% Ni, 20% Cr		20.00	80.00					G	G	E	G	G							G			F	G	P	G	G	E								
Hastelloy		14.00	58.00			Mo 17	W 5.0	E	E	E	G	E	E	E	E				E	G	G	G	FG	G	G	E	E	G	G	G	G	E	G	G	G
Commercially pure Cu					99.90			G	G	G	FG	G							FG	P	F	F	FG	P	FG	FG	FG					G	FG		
Copper alloys : Red brass					85.00	Zn 15.0		G	G	FG	FG	G							FG	P	P	P	FG	P	FG	FG	P					G	FG		
Tobin bronze					60.00	Zn 39.2	Sn .75	G	FG		F	G	F									P	F	P	FG	F	F					G	F	FG	
Phosphor bronze					95.00	Sn 5.0	Zn 1.5	G	FG		F	G							P	P	F	P	FG	P	FG	FG	FG					G	FG		
Silicon bronze				3.00	95.00	Mn 1.0 or	Sn .5	G	G		FG	G							G	P		F	G	P	G	FG	P					G	FG		
Aluminum bronze					90.00	Al 9.0	Fe .5	G	G		FG	G							FG	P		P	FG	P	FG	FG	FG						FG	G	
Nickel silver			20.00		75.00	Zn 5.0	Ni .5	G	G		G	G							G	P		F	G	P	G	G	G						FG		
Admiralty metal					70.00	Zn 29.0	Sn 1.0	G	G		FG	G							FG			P	FG	P	FG	FG	P						FG		
Commercially pure Al						Al 99.20		F	F	PG	P	F							G	G	G	P	P	P	F	P	P					P	F		
Commercially pure Sn										E										G	G	P	P	P	P	G	P	P				P			
Commercially pure Pb					0.06	Pb 99.90		G	G	PG	G	G							P	P	P	F	G	P	P	G	P	P					F		

E = Excellent; almost unlimited service
G = Good; will give good service
F = Fair; only to be used in temporary construction
P = Poor
FG = F to G PE = P to E PG = P to G
† E at low and P at high concentration
‡ Below 50°C.

Dairying — Equipment exhibited at the annual dairy conventions reveals the tremendous use of stainless, with universal satisfaction.



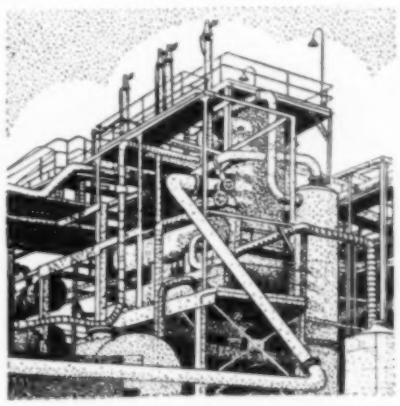
Food Industry — Fast frozen foods have opened a new field for stainless, especially for cabinets containing the frozen product and for conveyor tables used in processing the foods. Careful study has shown conclusively that stainless steel is not handicapped in its use as cookers because of a low heat conductivity. This is almost exactly counteracted by the film-forming characteristics of other metals which cut down their heating efficiency.

Refrigeration — It is expected that stainless will replace tinned steel trays or shelves in domestic refrigeration units. A large tonnage now goes into evaporators, ice cube trays and trim for the boxes.

Oil Industry — Recent developments in oil refining, which include the revolutionary catalytic processes, will require the use of millions of feet of high chromium steel tubing. In the higher temperature ranges, 18-8 stainless steel will be employed, grading down through the lower chromium alloys as the temperatures decrease. The pressures used in most catalytic treatments are low, and consequently the primary requirements are for oxidation and corrosion resistance. Another application that increases annually is the lining of tanks, vats, reaction chambers and retorts [a matter discussed on page 550 by Merrill Scheil].

Paper and Pulp — Newly constructed mills on the West Coast have used much stainless steel in evaporator tubes, circulating systems, save-alls, and perforated screen plates; usually the molybdenum type 18-8 is needed.

Textiles — Stainless has been used in increasing quantities for textile equipment since 1930, largely for wool dyeing and woolen and silk bleaching. New types of rayon need stainless steel for many steps in processing, and the consumption in such plants will depend, to a considerable extent, on the modified trading relationships with Japan, which may reduce considerably the importation of raw silk.



Railways — High strength stainless steel, used originally in the manufacture of high speed, light weight trains by the Budd method, is now being broadened by its use in trailer-truck bodies, milk truck tanks and bus bodies. A number of complete trains were ordered during the past year and several new ones are in prospect. Transportation applications represent a potentially tremendous outlet.

Modification of 18-8

By D. Carb
Pittsburgh, Pa.

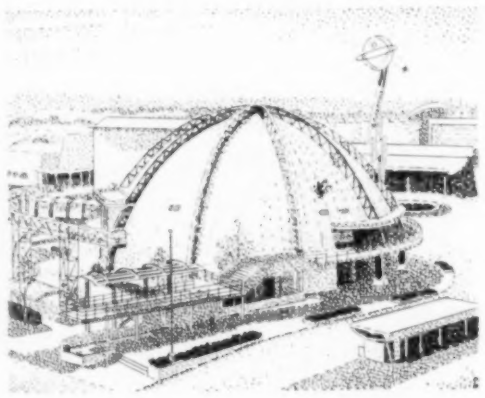
STAINLESS STEEL, which, by the way, because of our love for abbreviations, is known to the millions of consumers as merely "stainless", comprises several varieties. Much has been written about a grown-up child of the industry nicknamed 18-8. It also is an abbreviation — so widely adopted it should be ready for Mr. Mencken's "The American Language" — standing for an alloy containing 17% and upward of chromium, from 7% to as much as 10% of nickel, little carbon, and certain small amounts of other elements such as manganese and silicon.

While the enormous growth of its application is fully justified by its corrosion and mechanical characteristics, there is no doubt but that the flexibility or adjustability in the mechanical properties is also an important contributing factor. Whatever its fabricating problem may be, the solution can be materially helped by the proper selection of a specific analysis of the alloy within the rather broad limits stated a few lines back. The underlying reason is understood: The alloy, although exhibiting at room temperature the structure and physical characteristics of a solid solution (austenite), is in reality a metastable product, except perhaps at quite high temperatures. Its forming and fabricating habits are determined by the degree of metastability (if such an expression can be used!) because the metastable solid solution is changed in part to a stable mixture of phases by such

operations as cold working. And since the degree of metastability is the function of composition, various mechanical properties can be secured through an intelligent selection of analysis. High strength — as much as 225,000 psi.; ductility — either high or adequate, depending on the "must have" tensile strength; toughness — fully maintained at temperatures as low as —100° C.; fatigue strength — of high magnitude in the alloys properly processed; all these, the engineers have learned, are available in this remarkable family of alloys.

Other factors exert powerful influence on the maintenance of metastable constituents in 18-8 and similar alloys. Well known is the effect of heating to within a range, approximately 800 to 1500° F. Partial change in the austenite then occurs in certain preferred locations, an action known by various technical words. In practice (or in effect) it means that the alloy then loses much of its valuable corrosion resistance when subjected to a corrosive agent, either at elevated temperature or after cooling. Unless easy yet imperative precautions are taken when hot bending or forming, welding, riveting or soldering, the final product may be harmed.

The *extent* of the harm is influenced by numerous circumstances. Composition and the Cr-Ni-C ratio is one; length of time *at temperature* is another; nearness to the lower or upper limit of dangerous temperature range is another; previous heat treatment, sometimes spoken of as "de-sensitization", is still another. All these factors were found to affect the accepted cause of the difficulty — namely, precipitation of carbides at the grain boundaries, impairing their subsequent resistance to corrosion.



To understand a phenomenon is often the first step in eliminating it — if it is undesirable. Proper steps to be taken after fabrication, such as annealing at a temperature *above* the upper limit of the "carbide precipitation range", have, in many cases, solved the difficulty. Yet it is not an easy matter to anneal a huge vessel at 1950° F. or higher.

Continued search resulted in the finding of compositions, distinguished either by proper ratios of Cr-Ni-C or by the presence of some other elements, with enhanced resistance to "carbide precipitation". Of the elements that have been mentioned in this connection are tantalum, vanadium, titanium, and columbium. Titanium and columbium have been generally adopted commercially. The amounts required are relatively small, depending on the carbon content, since their function appears to be that of tying up or fixing carbon in an insoluble inclusion.

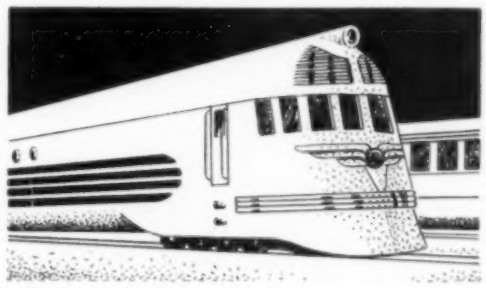
It is obligatory that added elements should not have a deleterious effect on general corrosion resistance. However, there is hardly a test in existence which would answer such an inquiry. From the accumulated data pertaining to relatively common corrosive media, it appears that neither columbium nor titanium has a serious effect. Titanium-bearing steel, tested in the standard nitric acid test, will show somewhat greater losses; the practical significance of this effect is negligible, unless some extraneous circumstance enters. Thus there appears to be little choice between additions of titanium or columbium, except in cases involving welding, when most of the titanium is lost at the joint through rapid oxidation. Columbium-bearing metal is generally recommended and employed for welded construction.

Various manufacturing or service conditions have necessitated various modifications in the 18-8 analysis, which, however, do not destroy its inherent nature. The outstanding among additions is that of molybdenum; one common commercial grade contains 2 to 3% and another contains 3 to 4%, with nickel raised to as high as 14%, mostly to aid in fabrication. Molybdenum prevents damage through local, isolated, so-called "pinhole" corrosion, experienced in sea water, in some chlorides, and in vapors of acetic acid.

Pinhole corrosion is local; the formation of pits bears no relation to any known factor either in fabrication of the alloy or in its inherent characteristics. "Purity" — in the sense of non-metallic inclusions — is, for example, of no consequence. Whether the metal is produced by the scrap process or any other, whether it is melted even in vacuum, has no effect either. For these reasons alone, the sim-

ple expedient of adding molybdenum to prevent possible serious pit corrosion is of major importance. (Alloys modified with silver, recently described as resisting pitting, are altogether in an experimental stage.)

To prevent intergranular corrosion and yet insure resistance to pinhole corrosion, additions of molybdenum and columbium were naturally investigated. Addition of two more elements to an alloy characterized by various degrees of metastability apparently creates a very complex metallic system, the behavior of which may be altered by factors either not yet understood or most difficult to control. Consequently, very encouraging as well as very discouraging results are known, and commercial use of this alloy has not yet arrived.



Some attention is being paid to alloys of the 18-8 type with increased percentages of manganese. Improved properties are said to include ductility, especially of the welds, and workability; up to 2% manganese is recommended. Manganese stabilizes austenite, much in the same manner as nickel; it would appear that these two elements, within limits, have similar effects on the above-mentioned properties and the same purpose may be accomplished by an increased amount of either. Thus, if the stated improvement is at all needed, the choice of either manganese (up to 2%) or nickel (raising it from 8% to 10%) becomes a personal one. This amount of manganese, as far as we were able to ascertain, has neither a beneficial nor a detrimental effect on corrosion resistance.

As is well known, silicon has a beneficial effect on the resistance to oxidation. Last year brought no new developments in this alloy. Additions of copper (up to 2%) and copper with molybdenum (about 1% of each) are offering improved corrosion resistance in certain corrosive media; the latter is recommended to resist sulphuric acid.

To the numerous varieties of "free machining" 18-8's is now added a lead content of 0.12 to 0.25%. Improvements in machinability are quite encouraging and since the non-corrosive properties of the alloy are said to be unimpaired, the "leaded" stainless steels deserve attention.

Light Weight Structural Fabrication

By E. J. W. Ragsdale
Edward G. Budd Mfg. Co., Philadelphia

THE RELATION between strength and weight of a metal construction has too often been discussed in METAL PROGRESS for there to be any necessity of further elaboration. We all know that new alloys and heat treatments have been commercially developed since the War that have met the requirements of aircraft—"requirements" is advisably used, for without them the aircraft would be merely a craft. We have wondered why it has taken engineers in other industries so long to adapt these new metals to mobile structures—automobiles, tractors, rolling stock, shipping. Perhaps it is because of that conservatism so adequately expressed by Octave Chanute, one of the leading bridge engineers of 50 years ago, in an address in 1882 before the American Institute of Mining Engineers (then the leading American metallurgical society) on "Iron and Steel Considered as Structural Materials":

"First, as to steel. While we all acknowledge that this is the material of the future, our position may be said to be still one of expectancy. Few engineers are bold enough to employ it largely in bridges, and those who do find such serious difficulties in obtaining uniform grades of it, are so puzzled by apparent anomalies and unexpected phenomena, that it requires considerable faith and courage to apply it in large structural masses..... At present we know that the strength exists, but we also know that steel is brittle under many conditions, and where human lives are at stake, where failure would involve such disastrous consequences, we dare not avail ourselves of the strength of that metal, unless reasonably sure that it will not break."

Evidently Mr. Chanute was still sticking to his wrought iron.

It is believed that the time has now arrived (1939) when the adaptability of standard or conventional design must be carefully examined to determine in what respects it is inadequate for the newer construction materials now available. Orthodox design obviously does not bring

Properties of the Principal Cr-Fe Alloys

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Chemical composition							
Chromium	1.75 to 2.25	4 to 6	8 to 10	12 to 14	13 to 14	16 to 18	25 to 30
Nickel	(0.5 Mo)	—	(1.5 Mo)	—	—	—	—
Si and Mn (max.)	0.50	0.50	0.50	0.50	0.55	0.50	0.50
Carbon	0.15 max.	0.10 to 0.20	0.15 max.	0.10 max.	0.30 to 0.40	0.10±	0.10±
Specific gravity							
Lb. per cu. in.	—	0.280	0.282	0.276	0.278	0.273	0.270
(Mild steel = 1.00)	—	0.99	1.00	0.97	0.98	0.96	0.95
Electrical resistance at 70°F							
Microhms per cm³	—	—	—	57	60	59	67
(Mild steel = 1.00)	—	—	—	5.2	5.5	5.4	6.1
Melting range, °F.							
Top	—	2800	—	2790	2750	2750	2750
Bottom	—	2760	—	2750	2580	2710	2710
Structure (normal)	Pearlitic	Pearlitic	Martensitic	Martensitic or Ferritic	Martensitic	Ferritic	Ferritic
Magnetism							
Ferromagnetic	Yes	Yes	—	Yes	Yes	Yes	Yes
Permeability: As annealed	—	—	—	—	—	—	—
Permeability: Cold worked 10%	—	—	—	—	—	—	—
Specific heat							
C.g.s. units, 0 to 100°C.	—	0.11	—	0.11	0.117	0.11	0.11
(Mild steel = 1.00)	—	1.0	—	1.0	1.1	1.0	1.0
Thermal conductivity							
*C.g.s. units at 100°C.	—	0.0874	—	0.0595	0.05	0.0583	0.0500
(Mild steel = 1.00)	—	0.73	—	0.50	0.42	0.49	0.42
C.g.s. units at 500°C.	—	0.0803	—	0.0686	—	0.0624	0.0583
Thermal expansion per °F. x 1,000,000							
From 32 to 212°F.	—	6.1	6.29	6.1	5.7	6.0	5.9
(Mild steel = 1.00)	—	0.93	0.95	0.93	0.87	0.91	0.90
From 32 to 932°F.	—	7.2	7.00	6.7	6.6	6.7	6.3

Mechanical Properties at Room Temperature	2% Cr Annealed	5% Cr Annealed	5% Cr †Heat Treated	9% Cr Annealed	12% Cr Annealed	12% Cr †Heat Treated	Cutlery Annealed	Cutlery ††Heat Treated	17% Cr Annealed	17% Cr Cold Worked (Wire)	27% Cr Annealed	27% Cr Cold Worked (Wire)
Ultimate strength, 1000 psi.	60 to 70	66	115	75 to 87	65	125	100	230 to 260	75	100 to 190	75 to 95	85 to 175
Yield point, 1000 psi.	30 to 45	27	103	35 to 45	35	100	65	200 to 220	40	—	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	—	—	—	—	28	—	—	—	29	—	—	—
Elongation, % in 2 in.	40 to 30	38	20	40 to 30	35	20	27	8 to 2	27	—	30 to 20	—
in 10 in.	—	—	—	—	—	—	—	—	—	25 to 2	—	25 to 2
Reduction of area, %	—	76	66	—	65	60	59	20 to 2	55	40 to 20	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	—	—	35 to 60	—	75	—	—	—	—	—	—
Izod	—	80	75	—	80	—	—	—	8 to 25	—	—	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	—	—	—	—	48	—	50	—
Corresponding ultimate strength									76		78	
Hardness, Brinell	130 to 160	136	250	145 to 180	140	230	170	480	175	185 to 270	160 to 190	150 to 250
Rockwell	—	B-75	C-24	—	B-76	C-22	—	C-56	B-85	B-90 to 105	B-80 to 90	C-0 to 25
Erichsen value, mm.	—	—	—	—	—	—	—	—	7 to 9	—	—	—

Stress in psi. causing 1% "creep" in 10,000 hr. at	1000°F.	11,400	7,000		11,600	13,000			8,500		—	
	1100	5,650	—		6,950	5,200			5,200		—	
	1200	3,150	—		2,300	2,100			2,100		1,600	
	1350	—	—		—	1,400			1,200		400	
Scaling temp., °F.			1200		1200	1300		1750	1550		2100	
Initial forging temp., °F.			2100		—	2100		2000	2000		2200	
Finishing temp., °F.			About 1400		—	max. 1450		1700	max. 1400		max. 1400 to 1450	
Annealing treatment			Furnace cool from 1580°F.		—	Prolonged heating at 1250 to 1350°F.		1575 to 1625°F.	**		1 hr. or more at 1450°F. and quench	

* Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.
† Quenched and drawn at 1100°F. †† Oil Quenched from 1850°F. and drawn.
** Small cold reduction, followed by anneal at 1400°F. and quench

Properties of the Principal Cr-Ni-Fe Alloys

	18-8		18-12	25-12	25-20	18-26
Chemical composition						
Chromium	17 to 19	Modification with titanium	17 to 19	22 to 28	24 to 26	17.5 to 19.5
Nickel	8 to 10		11 to 12.5	12 to 16	19 to 21	25 to 26
Si and Mn (max.)	0.50		0.50	—	1.0 & 0.75	3.0 Si max.
Carbon	0.10		0.10	0.15±	0.15 max.	0.20 max.
Specific gravity						
Lb. per cu. in.	0.286	0.285	0.287	0.283	0.285	0.280
(Mild steel = 1.00)	1.01	1.01	1.02	1.0	1.01	0.99
Electrical resistance at 70°F.						
Microhms per cm.³	70*	71	73	78	90±	102
(Mild steel = 1.00)	6.4	6.5	6.7	7.1	—	9.3
Melting range, °F.						
Top	2590	2590	—	2570	2600	—
Bottom	2550	2550	—	2530	2550	—
Structure	Austenitic	Austenitic	Austenitic	Austenitic	Austenitic	
Magnetism						
Ferromagnetic	—	—	—	—	Trace	—
Permeability — As annealed	1.003	1.003	1.003	1.003	1.003	—
Permeability — Cold worked 10%	1.10	—	1.006	1.003	—	—
Specific heat						
C.g.s. units, 0 to 100°C.	0.12	0.12	0.12	0.12	—	—
(Mild steel = 1.00)	1.1	1.1	1.1	1.1	—	—
Thermal conductivity						
**C.g.s. units at 100°C.	0.0390	0.0385	0.0380	0.03 to 0.04	0.03 to 0.04	—
(Mild steel = 1.00)	0.33	0.32	0.32	0.25 to 0.35	0.25 to 0.35	—
C.g.s. units at 500°C.	0.0515	0.0528	0.0520	—	—	—
Thermal expansion per °F. x 1,000,000						
From 32 to 212°F.	9.6	9.3	9.9	8.3	8.8	8.8
(Mild steel = 1.00)	1.45	1.40	1.50	1.26	1.33	1.33
From 32 to 932°F.	10.2	10.3	10.8	9.6	9.4	9.3

Mechanical Properties at Room Temperature	18-8 Annealed	18-8 Cold Worked (Wire)	18-8 †Stabilized	18-12 Annealed	18-12 Cold Worked (Wire)	25-12 Annealed	25-12 Cold Worked (Wire)	25-20 Annealed	18-26 Annealed
Ultimate strength, 1000 psi.	80 to 95	105 to 300	80 to 95	80 to 90	105 to 225	90 to 110	110 to 270	80 to 110	90 to 110
Yield point, 1000 psi.	35 to 45	60 to 250	40 to 45	40	—	40 to 60	65 to 230	35 to 65	45 to 50
Elastic modulus, 10^6 psi.	29	—	—	—	—	—	—	—	30±
Elongation, % in 2 in.	65 to 55	—	60 to 50	60	—	50 to 35	—	60 to 45	35 to 30
in 10 in.	—	50 to 2	—	—	50 to 2	—	35 to 2	—	—
Reduction of area, %	65 to 55	65 to 30	65 to 55	65	65 to 30	60 to 45	55 to 20	—	45 to 35
Impact, ft-lb.; Charpy	80	—	77	—	—	—	—	40 to 80	—
Izod	75 to 110	—	—	—	—	—	—	—	50 to 90
Fatigue endurance limit, 1000 psi.	35	94	48	—	—	52	—	—	—
Corresponding ultimate strength	90	150	90	—	—	110	—	—	—
Hardness, Brinell	135 to 185	170 to 460	135 to 185	135 to 165	170 to 380	150 to 185	170 to 375	130 to 190	160 to 185
Rockwell	B-75 to 90	C-5 to 47	B-75 to 90	B-75 to 85	C-5 to 40	B-80 to 90	C-5 to 40	—	—
Erichsen value, mm.	11 to 14	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	17,000							—	7,000
1200	7,000							2,400	—
1350	3,000							3,300	—
1500	850							1,100	—
1600	—							—	1,900
Scaling temp., °F.	1650		1650	1650		2100		2000	1650
Initial forging temp., °F.	2200		—	As for 18-8		2200 to 2300		—	1950
Finishing temp., °F.	Not under 1600 to 1700		—	As for 18-8		Not under 1600 to 1700		—	—
Annealing treatment	Heat at 1900 to 2000°F. and quench		††	As for 18-8		Heat at 2000 to 2150°F. and quench		—	As for 18-8

* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm. cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

† Small cold reduction, followed by anneal at 1400°F. and quench

†† Final heat treatment must consist of 2 to 4 hr. soak at 1550°F.

out the potential savings of those new materials whose lightness and indestructibility are capable of being utilized.

It is believed that the principal reason why the potential savings of the high tensile steels, strong aluminum alloys and stainless steels cannot be fully realized is that the orthodox design has always contemplated solidity by *continuity* of metal from a central axis as distinguished from the *cellular* form of structure. Typical examples of cellular construction are found in corrugated culvert pipe or in the airplane member. These are built of light tubing or corrugated sheet welded rigidly together as in the shotwelding process.

Now designs should enable a greater use of the high tensile and high elastic ratio steels by development of the properties of the cellular type. This would lead at once into a search for information on the properties of welded connections and this in turn would involve a study of the mechanical and metallurgical properties as influenced by manufacture and fabrication. The importance of such studies is evidenced by the fact that already several technical societies have made investigations of the effect of cutting and welding processes on these newer steels which are rapidly becoming indispensable for the largest structures.

It is therefore suggested that a research be organized and sponsored by a group built up from agencies such as those named below. A board would be designated consisting of approximately half a dozen engineers of national reputation who would advise as to the plan of the research. It is visualized that such a group would set out in detail new designs which would be investigated, and lay out the incidental features of fabrication and subsequent testing.

Numerous American engineering societies would readily cooperate, especially those interested in metals, welding, structures, bridges, machines, aeronautics, automobiles, railroads and shipping. Many corporations manufacturing the steels, ferro-alloys and welding equipment, as well as others actually doing the fabrication, might be expected to join actively in the prosecution of the research.

Re-examination of existing product is a periodic task of highest importance to up-to-date firms in all lines of endeavor. It is time that engineers and engineering firms re-examine the fundamental basis of their design. It is a minimum insurance policy.

Aging at 400° F. improves
Cold Worked 18-8

By Russell Franks
Union Carbide & Carbon Research Laboratories, Inc.
Niagara Falls, N. Y.

THE EVER-BROADENING USE of the 18-8 steels for resisting corrosion has led to their application for many purposes, and the construction of light weight, high strength structures offers no exception. As is well known to readers of METAL PROGRESS the steels are austenitic in character, and high strengths are readily obtained by cold working, consequently in recent years such products have been extensively used for the construction of high speed trains and many other light weight structures, including aircraft wings, spars and other details.

Recent research work has yielded information that will undoubtedly still further extend their application. It shows that if the cold worked metal is heated to about 400° F. and air cooled it will acquire better elastic properties than the cold worked metal before such mild treatment. Cold rolled 18-8 steels so treated exhibit a modulus of elasticity of approximately 28,000,000 psi., which is about normal for the annealed 18-8 steel. The treatment raises the proportional limit and yield stress and makes the steels stiffer in the plastic range below the yield stress. It accomplishes these results without impairing tensile strength, ductility, or the bright cold rolled surface. The slight yellowish oxide coating developed during the heating period can readily be removed by dipping in a hot nitric acid solution, which solution, at the same time, passivates the surface in a very desirable manner. The treated steels retain the high fatigue resistance and toughness characteristic of these alloys and their resistance to intergranular corrosion or general corrosion is not impaired.

Length of such heating period is important; it should be long enough to insure that the improvement in elastic properties is substantial and uniform. In general, it varies from a few hours to an aging of no more than 72 hr. in the range 350 to 450° F. and is followed by air cooling.

This development should result in a wider application of cold rolled 18-8 steels in aircraft construction and other light weight structures both large and small.

Metals for the Power Industries

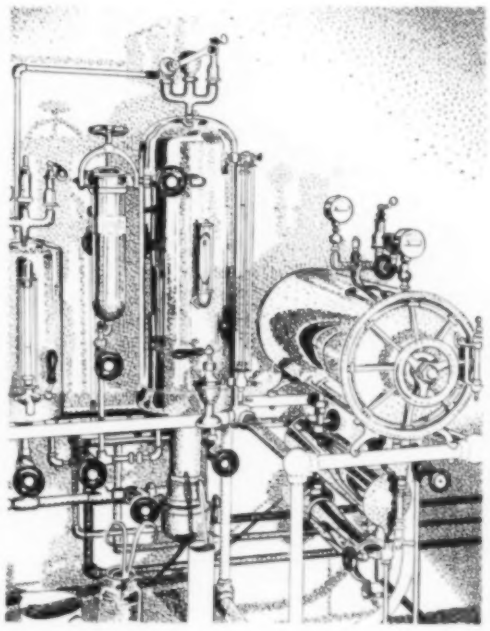
By J. J. Kanter
Research Metallurgist, Crane Co., Chicago

THE PROBLEM in the power industries of utilizing the greater efficiencies possible through high operating temperature and pressures in steam power plants, stands as a direct challenge to the metallurgist to develop suitable materials. Steam turbine operation has been demonstrated practical at 1000° F. in stationary plants, and perhaps this temperature will remain as a good one for new installations for some time to come. In marine plants, due to maintenance limitations, and generally greater hazards, operating temperatures of 850° F. are the highest visualized at present. Locomotive steam operating temperatures are even more modest, none contemplated above about 725° F.

Noteworthy is the trend of high temperature piping steels toward weldable compositions. Joints which were formerly bolted, are rapidly being supplanted by welded assembly. Welded construction is now being used to replace even the bonnet flanges on high pressure steel valves, and this effects very substantial weight savings.

Much activity is evidenced in committees of the American Society for Testing Materials in preparing specifications for the weldable high temperature piping materials to meet the power industry's requirements. Tentative specifications have recently appeared defining welding grades of pressure castings and piping. The Boiler Code Committee is actively engaged in preparation of values for allowable working stress, based on creep data, for all types of materials used in high pressure equipment.

Of the carbon steels used in high pressure work, the silicon-killed variety is favored wherever service temperatures exceed 750° F. because of its definitely higher creep strength over the rimmed steel. For service temperatures exceeding 850° F., carbon-molybdenum compositions have been widely accepted for both piping and castings.



The use of stainless steels in steam power equipment is somewhat limited, being confined largely to turbine blading, superheater tubes of the 18-8 type, and modifications thereof, when temperatures of 1000° F. or higher are encountered, and for some valve trim, particularly for stems. Hard surfacing materials, or overlays of the stellite type, have proved highly successful as seating surfaces in large valves operating at temperatures of 850° F. and higher, where difficulty due to seizure and galling has been experienced with the straight chromium alloys.

Stainless Equipment
prevents contamination of product

By H. L. Maxwell
Technical Division, Engineering Department
E. I. duPont de Nemours & Co.,
Experimental Station, Wilmington, Del.

ECONOMICAL application of large tonnages of stainless alloys in chemical plant equipment continues to require active attention. The plant applications most publicized are those where process conditions are so corrosive as to require highly resistant metals in order that the equipment may operate for an economical time before it needs reconditioning or replacing. In this class is found such equipment as *(a)* ammonia oxidation to produce nitric acid, *(b)* synthesis of organic acids, and *(c)* the manufacture of a wide variety of organic compounds, most of which require the application of temperature with or without considerable pressure.

In addition to the urgent question of continuity of operation, another of paramount importance is the matter of product *quality*, which is determined largely by the freedom from metallic pick-up from the equipment. For example, the washing, filtering, and calcining of white pigments may be carried out in equipment fabricated from one of several different metals, any of which will give reasonable life. Of more importance, however, than life of the

equipment in this instance, is the freedom from contamination of the product.

There are numerous other cases in the production of both fine and heavy chemicals where the corrosion rates of carbon steel and iron are sufficiently low as to guarantee practically permanent life in production service. As far as durability is concerned the least expensive metal will suffice, but this does not hold true as regards contamination. Certain steps in the process production of rubber compounding chemicals, dyes, and esters, corrode ordinary steel so little that the rate cannot be determined experimentally, yet the small amount of heavy metal contamination would result in off-quality product.

It is sometimes possible to use stainless-clad carbon steel with initial installation economies ranging from 15 to 25% and still gain the advantage of having a stainless metal in contact with the product. The commercial production of columbium-stabilized 18% chromium, 8% nickel stainless steel has done much to promote the use of clad vessels in certain of these so-called contamination processes. The advantage is that the completed vessel can be given a 1250° F. stress relieving treatment which leaves both the stainless cladding and the heavy carbon steel base metal in satisfactory condition for plant service.

Just as stainless steel is being used in the more widely known applications of combating corrosion and extending equipment life, it is also being used to an increasing degree as an insurance policy against the contamination of chemical products.

Lined Equipment in Corrosive Service

By Merrill A. Scheil
Research Metallurgist
A. O. Smith Corp., Milwaukee, Wis.

THERE IS A WIDE FIELD of application for alloy lined equipment in the petroleum, chemical, and other process industries. However, a word of caution about the selection of lining material is timely. Before a certain material is specified, it is advisable to study the contemplated service thoroughly and to make a sufficient number of tests to insure that the material selected will meet all the conditions that may be encountered. The purchaser of lined equipment should also appreciate that the selection of the proper alloy depends to a large extent upon his cooperation. In other words, unless the fabricator's preliminary tests duplicate all of the possible conditions in the contemplated service, the results will be of little value or may even be misleading.

As fabricators of both lined and solid alloy vessels, we have found that each new corrosion problem has to be treated individually. Continued success and future expansion of the use of alloys for linings will, therefore, depend upon thorough knowledge and application of metallurgy to the problems involved in each case. Only those companies which have facilities and knowledge for specifying the proper material, for ascertaining that the material received meets the requirements and for the correct application of this material in the fabrication of the equipment involved, can hope to be of real service to the industry.

One of our recent developments in the field of lined equipment is arc welding of seams in the lining, with full penetration and without iron dilution from the base metal. Another development involves the use of special methods of fabrication and testing, whereby it is now possible to make a 100% test of the lining for bottle tightness during construction, as well as when desired throughout the service of the equipment.

The following corrosion resisting materials are being successfully applied as linings in carbon steel equipment:

18-8: Types 304, 306, 308.
18-8 Ti: Types 320, 321.
18-8 Cb: Types 345, 346, 347, 348.
18-8 Mo: Types 316, 317.
11-13 Cr: Types 403, 405, 410.
14-18 Cr: Types 430, 431.
Hastelloy A.
Nickel.
Monel.
Inconel.
Cupro-nickel: 70-30.

These materials have been used to line such process equipment as heat exchangers, condenser shells, cookers, digesters, kettles, fractionating towers, evaporator towers, separator towers, chemical autoclaves, storage tanks and caustic pots. In addition experimental work has indicated that it will be possible in the near future to supply equipment lined with Hastelloy B, Hastelloy C, 25-5-3 (Type 329), and 25-20 (Type 310).

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The A-B-C of Corrosion and Heat Resisting Steels

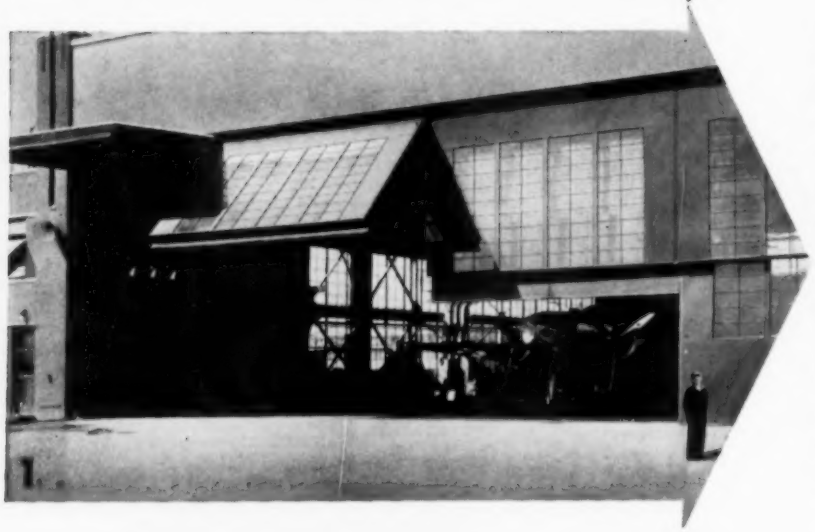
Arrangement due to F. R. Palmer. Adapted from The Book of Stainless Steels, Second Edition

Group A (Martensitic)	Group B (Ferritic)	Group C (Austenitic)
Chemical Analysis Chromium less than about 16%; carbon less than about 0.40%. May contain small percentages of tungsten, copper, nickel, silicon, columbium, aluminum, and more frequently molybdenum. Group is magnetic.	Chromium more than about 16%; carbon quite low, but can increase as chromium goes up. May contain small percentages of copper, nickel, silicon, molybdenum, tungsten, nitrogen. This group is magnetic.	Contains enough nickel to make steel austenitic and non-magnetic. They usually contain twice as much chromium as nickel or vice versa; total alloy content at least 26%. Carbon quite low. (Manganese sometimes substituted for nickel, in part.)
Heat Treatment Respond to hardening and tempering. Resulting physical properties depend on chemical analysis (principally carbon content).	Do not respond. 18% chromium toughened by long anneal at more than 1400° F., and air cooling. Avoid decarburizing the skin. 25% chromium gets best strength and toughness by rapid cooling from 1650°.	Do not respond to hardening by heat treatment. Must be rapidly cooled from soaking heat at 1900 to 2150° F. to retain austenitic structure free of carbides. (Brinell 140 to 170).
Toughness Are structurally dependable. After tempering are not brittle in notched sections or under impact.	Laminated structure, from coarse ferrite in ingot, causes low impact values, but proper rolling and heating gives adequate toughness in rods, bars, and sheets. Structure is refined by alloying with nitrogen.	Extremely tough at all temperatures down to liquid air. Dependable against shock except when corroded at grain boundaries (a preventable condition).
Grain Growth and Structural Changes at High Temperatures Not subject to excessive grain growth. Thoroughly dependable for supporting any load or shock within their carrying capacity up to 1400° F. Brittleness in plain chromium steels when cooled after long heating is avoided by addition of molybdenum.	The chromium-irons low in carbon and those high in silicon or aluminum (when cold worked) are subject to excessive grain growth, especially above 1900° F. Grain growth reduced by nitrogen. Long service at 800 to 950° F. makes them brittle when cold, although they are not brittle at working temperatures.	Alloys near the austenite-martensite border line tend to precipitate carbides at grain boundaries during service at 800 to 1600° F., losing some toughness and becoming susceptible to intergranular attack. This is controlled by very low carbon, by titanium or columbium, by increasing the chromium and nickel, or by prior "stabilization."
Strength at Elevated Temperatures Much better than straight carbon steel for temperatures up to 1000 or 1200° F. Retain tensile properties up to 750° F.	Heat resisting varieties quite tough at temperatures up to 1600° F. Superior in ductility to Group C but not in creep resistance.	Have high creep strength up to 1200° F. which is enhanced by tungsten or molybdenum. Toughness impaired in non-stabilized alloys by service at 800 to 1600° F.
Hot Working Qualities Readily forged, pierced, or rolled at 2000 to 1700° F. Preheat and soak stock at 1600° F. Plain chromium alloys air harden on cooling.	May be forged, rolled, or pierced. Should be heated quickly. Forge from 2200° F. down to 1750° F. On last heat continue cold working to 1400° F. to refine grain. Alloys do not air harden.	May be forged, rolled, or pierced. Preheat and soak at 1600° F., heat quickly to 2200° F., forge down to 1850° F. Hot short range: 1800 to 1300° F. Alloys do not air harden.
Cold Working Qualities Low carbon varieties can be easily cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn.	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn, especially when warm (300 to 500° F.).	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn. Work-harden twice as rapidly as Groups A and B.
Machinability Machine satisfactorily with properly designed tools when heat treated to 200 to 250 Brinell. Free-cutting grade contains complex sulphides or selenium.	Machine satisfactorily with properly designed tools. Cold working and high sulphur or selenium improve machinability.	Most difficult of all even with super high speed and carbide tools. Use sharp tools having greater top rake than usual, and cut continually. Free-cutting grade contains selenium and phosphorus.
Riveting Make excellent cold rivets. Air hardening, high chromium steels not recommended for hot rivets driven above 1500° F.	Extra precautions required to avoid brittle rivets. Conical heads should be cold upset on ground bars; rivets driven at 1425° F. into chamfered holes.	Excellent for either hot or cold rivets. Hot rivets may be driven at a high temperature (1900° F.).
Welding Properties Preheated parts can be welded with gas, electric arc, or resistance. Anneal immediately before weld air hardens. Little grain growth. Columbium or aluminum increases ductility of welds.	Can be welded. Anneal at 1450° F. to reduce embrittlement alongside weld. Those metals subject to grain growth are brittle adjacent to the weld. Those metals not subject to grain growth yield satisfactory welds.	Can be welded with gas, electric arc, or resistance, if carburization is avoided. Weld does not air harden and is very tough. Only the relatively low carbon or "stabilized" metal should be welded if article must resist corroding media.
Corrosion Resistance Increases with chromium content; inferior to Groups B and C. Resists weather, water, steam, and mild corrodents when chromium is 11.5% or more. If carbon is relatively high, metal must be hardened and tempered (below 1000° F.).	Possess corrosion resisting properties superior to Group A; increases with chromium content. Especially good for nitric and other oxidizing acids.	Corrosion resistance depends largely upon total alloy content. Resists nearly all corrodents measurably better than Groups A and B; especially good for organic acids. Severe pitting may occur in stagnant chloride solutions under particles of foreign matter and along faying surfaces.
Scale Resistance Increases with chromium content. Generally useful for continuous temperatures up to 1200° F., and in some services up to 1500° F.	Superior to Group A, especially when chromium is above 25%; then resist reducing atmospheres up to 2100° F., resist oxidizing gases up to melting points, and sulphur gases up to 1800° F.	Excellent where combination of high temperature and corrrosion is to be met. High chromium, low nickel alloys required to resist sulphurous gases. Addition of 2 to 3% silicon markedly improves scale resistance.

1. DEPENDABLE
2. EFFICIENT
3. ECONOMICAL

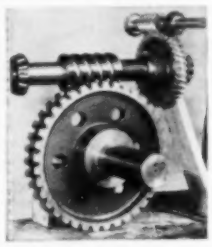
. . . these alloys of

NICKEL



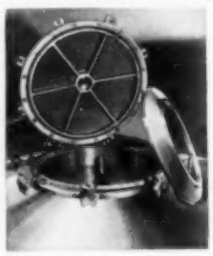
1. *HANGAR MAINTENANCE:*

The Dominion's largest doors, on Trans-Canada Airway's new hangars, are opened and closed by Nickel steel worms and chill-cast Nickel bronze gears. To obtain tensile strength of 51,000 p.s.i. the Richards-Wilcox Canadian Co., Ltd., London, Ontario, Canada, specified these gears cast with this composition: copper, 87.50%; tin, 11.00%; Nickel, 1.50%. The addition of Nickel to bronze improves density and strength without impairing anti-frictional qualities of gear surfaces — assures long trouble-free service life.



2. *BOTTLING OPERATIONS:*

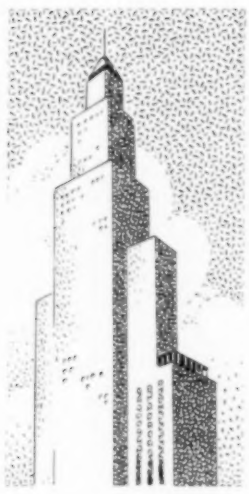
Metals used in bottling equipment must be corrosion resistant, strong, bright and attractive and be able to withstand repeated cleaning operations. Above all they must be non-contaminating to safeguard the beverages with which they come in contact. Solid Nickel Silver possesses these improved properties. Combining good structural qualities with resistance to corrosives, and eye appeal, it can be readily and repeatedly cleaned because there are no platings or coatings to wear away or flake off. Therefore, the Crown Cork and Seal Co., Baltimore, uses Solid Nickel Silvers for many parts of their high speed bottling and capping machines which come in contact with the beverages.



3. *FOUNDRY PRACTICE:*

Shrinks and cracks forced remelting of one of every four swing spout fixtures! That was the unprofitable record of the Universal Brass Manufacturing Co., Los Angeles. Rejects ate the heart out of profits. By adding 1% Nickel grain structures were refined making castings so pressure-tight and sound, that 90% of rejects were avoided. The uniformity of Nickel-bronzes cuts machining costs, too. Consultation is invited on money-saving applications of Nickel alloyed materials.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.



Stainless Steel Covering
fabric or mineral composites

By George S. Starke
Manager, Ludlite Division
Allegheny Ludlum Steel Corp., Watervliet, N. Y.

INTEREST in bi-metals and lined equipment, wherein stainless steel and carbon steel are used in conjuction, should include the combination of stainless steel with a non-metallic backing. Such material has in fact been available for some years, and marketed by the author's firm as "Ludlite Flex". This uses a paper thin sheet of 18-8 stainless combined with an inert and weather-resistant backing. It is about as flexible as stiff cardboard, may be cut with tinsmith's shears, is bent or shaped to fit any type of surface, and to which it may be cemented as readily as linoleum. The user can get this in sheets, ribbon or tile, and it has been applied in numerous ways as a surfacing material for decoration and sanitation.

During the last year we have perfected machinery whereby thin sheets of 18-8 (0.0095 in. thick) are cemented to a mineral backing material composed of asbestos, volcanic clay, calcined magnesite and cement. This is fireproof and weather resistant. Such "Ludlite Bord" is either ⅛ in. thick, flexible enough to be readily bent, or ¼ in. thick, a rigid and load carrying member. It is believed that this structural material, which can be cut and worked with ordinary carpenters' tools with no more difficulty than hard wood, will be very useful for wall coverings, for partition construction, and for sanitary linings of refrigerator rooms or food carrying cars and trucks. It, for instance, has already been specified for shower stalls in the first group of buildings for Boulder Dam National Park.

High Chromium Alloys

By H. Schultz
Chief Metallurgist, The Calorizing Co., Pittsburgh

WHILE heat resisting castings of the nominal analysis 25% chromium, 10% nickel have been widely used for still tube supports by the petroleum refineries, and for other load-carrying parts in furnace mechanisms, it has been found that many have become embrittled after considerable service. Oil still tube supports, wall brackets and roof hangers are subjected to uneven heating conditions — the projecting portions are always hotter than the parts bolted to the cold steel work outside the still. Since these high alloys have a large coefficient of expansion, severe temperature stresses are induced, and considerable ductility at all temperatures and after many temperature fluctuations is necessary to prevent the part from cracking and eventual rupture.

Fortunately it happens that an unstable alloy — "unstable" in the sense of losing its ductility in service — can be detected by a preliminary test requiring only 24 hr. at 1400° F. Twin test pieces — one pulled in tension in the as-cast state, and the other pulled at room temperature after such heating — give figures that are quite indicative. In the as-cast condition such an alloy may show 30% or more elongation in 2 in., but after 24 hr. heating an "unstable" alloy (in the above sense) will have less than 5%.

Creep value and residual ductility in certain types of 25% chromium, 10% nickel analyses are apparently associated with each other. High resistance to creep can be secured by increasing the carbon or nitrogen content, but the ductility suffers after heating and cooling in service. High residual ductility (more than 10% instead of less than 5%) can be secured by reducing the carbon to the neighborhood of 0.35%, but creep resistance suffers. A combination of both desirable properties may be had in 0.35% carbon alloys of this type containing also 0.10% nitrogen and 1.0% molybdenum. Results on 38 heats are as follows (tested at room temperature after 24 hr. at 1400° F.):

Ultimate tensile strength: 87,300 to 98,500 psi. (average 92,500 psi.).

Yield (load at 0.006 in. extension in 2 in.): 35,750 to 54,550 psi. (average 41,000 psi.).

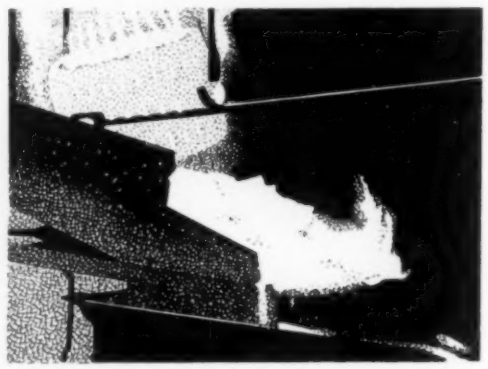
Elongation in 2 in.: 11.5 to 30.5% (av. 21.5%).

Representative heats tested for creep by the

Department of Engineering Research at University of Michigan gave the following results:

Temperature	Stress, Psi.	% Creep in 10,000 Hr.
1400° F.	4100	0.8
1600	3100	0.8
1800	1800	0.55

All these facts have led to specification requirements dividing the high chromium alloys into four grades, the highest of which shall have minimum ultimate strength of 80,000 psi., minimum yield of 35,000 psi., and minimum elongation of 9% in 2 in., all after heating 24 hr. at 1400° F. and furnace cooling. All heats of highest grade shall have a 1000-hr. creep test made on them within the range of 1400 to 2000° F. and must exceed minimum values such as 3600 psi. for 1% in 10,000 hr. at 1400° F., 2600 psi. at 1600° F., and 1600 psi. at 1800° F.



It may be of interest to record the design recommendations: Design stress in tension shall be figured on room temperature tests with factor of safety of six, or a figure based on expected life and creep strength (1% creep in 10,000 hr.), whichever gives the smaller value. If the life is 2 years, 65% of creep strength should be used; if 4 years, 60% of creep strength; 6 years, 55% of creep strength, and if 8 years 50% of creep strength. Bearing stress may be 1.8 the tensile, and stress in single shear 80% of the tensile. Highest grade castings should be computed to lose by oxidation the following: At 1800° F., 0.003 in. per year; at 1900° F., 0.005 in. per year; and at 2000° F., 0.007 in.

It is expected that the results of advanced alloying and foundry practice will largely increase the utility of these less expensive but remarkably heat resistant alloys.

Heat Resisting Alloys
up to 35% nickel

By R. J. Wilcox
Chief Metallurgist
Michigan Steel Casting Co., Detroit

CONSIDERABLE ATTENTION has been directed to the group of heat resisting alloys of the iron-chromium-nickel family containing 35% nickel and under. While the higher alloys containing up to 80% nickel indicate the best stability against carburization and certain types of chemical attack at elevated temperatures, the lower nickel compositions have assumed greater engineering significance in the design of structures and parts built to withstand temperatures up to 2100° F.

Since the soundness and metallurgical cleanliness of the alloy casting frequently measure the difference between success and failure of a particular unit, much attention and research effort is being directed toward problems of "castability", molding sands and refractories, processes of solidification and methods of feeding. Centrifugal casting technique has been improved and some of the earlier difficulties have been overcome with a resulting improvement in such tubular products, and an expanding field of utility.

Much work has been accomplished in determining the effects of such elements as silicon, manganese, calcium, nitrogen, titanium and vanadium on casting characteristics, structural stability, and soundness in castings for pressure service. The use and control of such elements has improved foundry practice. With such investigations still in progress it is anticipated that in the not too distant future, sufficient control data will be accumulated to indicate continued economies in production, and produce an even closer approximation to the metallurgical ideal.

Heat resistance, like corrosion resistance, is a relative term. When considering a specific alloy subject to the conditions of service, the prime considerations are usually structural stability and resistance to chemical attack, thus assuring a reasonable degree of permanence in load carrying ability. While the most frequently used heat resisting alloys are relatively rich in nickel and chromium, much interest has been extended to the lower alloys (such as the 12% to 15% chromium alloys and the 5% chromium steels) and for milder conditions even the alloy structural steels. Thus A.S.T.M. Specification A157-36 for "Alloy Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750° F. to 1100° F." includes six types of ferritic steels from the carbon-molybdenum steel to the 13% chromium steel, and two types of austenitic steels, an 18% chromium,

8% nickel alloy and a 20% nickel, 8% chromium alloy. For temperatures in excess of approximately 1100° F. it is usually necessary to use one of the higher alloys — such as the 25% chromium, 12% nickel, or the 25% chromium, 20% nickel, or the 35% nickel, 15% chromium — depending upon the chemical conditions encountered.

Also of considerable importance are the heat resisting cast irons, such as the austenitic nickel-chromium and nickel-copper-chromium types (advertised under the trade-name "ni-resist") as well as the high chromium cast irons containing 24% chromium and upwards.

As illustrated by C. E. MacQuigg in "The Book of Stainless Steels", the major function of chromium in the heat resisting alloys is to impart resistance to oxidation, and resistance, under oxidizing conditions, to sulphur and oxides of nitrogen at temperatures up to 2100° F. An examination of his curve indicating oxidation losses at 1800° F. illustrates that not until approximately 5% to 7% chromium is reached is there any significant improvement in scale resistance. At that analysis the loss from oxidation is about one third that of steels containing no chromium. For relative non-scaling properties at 1800° F., the curve indicates that it would be necessary to have some 20% or more of chromium in the absence of nickel. This laboratory conclusion is approximately substantiated in commercial practice.

Recent developments in the 4% to 6% chromium steels are reported to have improved its scale resisting properties up 1500° F., by the addition of substantial quantities of silicon, titanium or aluminum. Approximately 0.50% molybdenum is reported as desirable in this alloy to enhance high temperature strength and prevent temper brittleness.

For major heat resisting applications, however, involving temperatures of approximately 1100° F. to 2100° F., it is necessary to use the higher alloy compositions previously referred to, having a minimum of 15% chromium together with sufficient nickel to impart satisfactory chemical and structural stability. Under oxidizing conditions, the 35% nickel, 15% chromium alloy has, I believe, the best combination available of strength and permanence at temperatures as high as 2100° F. For sulphur bearing atmospheres, the 25% chromium, 12% nickel alloy finds favor with furnace builders; it has strength values closely approximating the 35-15 alloy first mentioned.

Heat Resisting Castings
nickel-chromium series

By H. H. Harris
President, General Alloys Co., Boston

IT HAS BEEN PROVEN by laboratory investigations and borne out by service under widely varying conditions that high nickel, low chromium alloys are better suited for high temperature service (that is, from 1000 to 2200° F.) than are the high chromium, low nickel varieties. The only exception is where sufficient sulphur is present to cause destructive attack.

However, when we come to the question of the physical properties of high temperature alloys, considerable mis-information exists. In the first place it is often forgotten that the properties are determined not only by the nickel and chromium content, but are influenced by the ever-present carbon, silicon, manganese, and by other alloying elements intentionally added. Likewise it is most important that we recognize that wall section of castings influences grain size, thence physical properties, particularly its sustained ductility after high temperature service. Thin wall means fast cool — finer grain. Thick wall means slow cool — coarser grain. Furthermore, the physical properties, tested cold, of any of these alloys to be used in high temperature service give no indication of the capacity to resist strains and stresses arising from temperature reversals.

The table from Alloy Casting Research

Tensile Properties of Heat Resisting Alloys

	24% Cr, 12% Ni	60% Ni, 15% Cr	35% Ni, 15% Cr
As-Cast, Tested at Room Temperature			
Tensile strength	70,000	66,000	64,000
Proportional limit	21,000	15,800	14,000
Yield strength	40,000	34,000	36,500
Elongation	15.0%	4.5%	5.2%
Reduction of area	16.0%	5.5%	6.1%
Castings After Heating 48 Hr. at 1600° F., Tested Cold			
Tensile strength	78,000	75,000	73,000
Proportional limit	22,000	17,000	17,000
Yield strength	47,000	35,000	39,000
Elongation	4.0%	4.4%	4.4%
Reduction of area	4.5%	5.5%	5.3%
Short Time Tensile Properties at 1800° F.			
Tensile strength	12,000	9,900	11,000
Proportional limit	5,000	2,200	5,000
Yield strength	8,000	6,200	8,000
Elongation	27.0%	42.5%	32.3%
Reduction of area	45.0%	50.2%	46.3%

Engineering Properties of Monel Metal

Data from
International Nickel Co., Inc.

MONEL METAL is a solid solution of nickel and copper approximately 67:30, with added elements to control certain properties. Typical compositions are as shown at right:

PRODUCT	NI	CU	FE	MN	SI	C	AL	S
Wrought; Regular	67	30	1.4	1.0	0.1	0.15	...	(Note)
"K" (heat treatable)	66	29	0.9	0.4	0.25	0.15	3.3	0.005
Cast; Regular	67	29	1.5	0.9	1.25	0.3	...	.....
"H" (high strength)	65	29.5	1.5	0.9	3.0	0.1	...	.....
"S" (non-galling)	63	30	2.0	0.9	4.0	0.1	...	.....

(Note) A high sulphur variety called "R" Monel is free machining.

Properties of Monel Metal Castings

PROPERTY	REGULAR	H MONEL	S MONEL
Tensile strength (1000 psi.)	60 to 80	70 to 90	90 to 115
Yield (1000 psi. for 0.5% extension)	30 to 40	45 to 65	70 to 90
Elongation (% in 2 in.)	40 to 20	20 to 10	3 to 1
Izod impact, ft-lb.	65 to 80	35 to 45	1 to 5
Brinell hardness	125 to 150	170 to 210	280 to 325
Rockwell number	55 to 75-B	.....	<32-C

Temperature for slight oxidation ..... 570° F.
Annealing range (standard monel) ....1400 to 1800° F.
Forging range (standard monel) .....1600 to 2150° F.
Pouring range for castings .....2750 to 2900° F.

Cold-Rolled Sheet and Strip

TEMPER	SHEET		STRIP		APPROX. TENSILE STRENGTH
	SHORE	ROCKWELL B	SHORE	ROCKWELL B	
Dead soft	<16	<60	<16	<60	70,000
Soft	.....	.....	17 to 18	61 to 68	75,000
Soft skin-hard	17 to 20	61 to 73	.....	.....	.....
Skin hard	.....	.....	19 to 20	69 to 73	77,500
Quarter hard	21 to 24	74 to 82	21 to 24	74 to 82	80,000
Half hard	25 to 30	83 to 89	25 to 30	83 to 89	90,000
Three quarter	31 to 35	90 to 93	31 to 35	90 to 93	100,000
Hard	36 to 40	94 to 97	36 to 40	94 to 97	110,000
Full hard	.....	.....	>40	>97	120,000

Physical Constants of Wrought Monel

Specific gravity 8.80

Density, lb. per cu.in. 0.318

Melting range
degrees F. .....2370 to 2460
degrees C. .....1300 to 1350

Specific heat at (80° to 212° F.)
(27° to 100° C.) 0.127

Heat expansion coefficient
at 80° to 212° F., per °F.....0.0000077
at 25° to 300° C., per °C.....0.000015

Thermal conductivity
at 30° to 212° F., B.t.u./sq.ft./hr./° F./in. 175
at zero to 100° C., cal./sq.cm./sec./° C./cm. 0.06

Electrical resistivity
at 32° F., ohms/circ.mil.ft. 256
at 0° C., microhms/cm.³ 42.5

Temperature coefficient of electrical resistivity
per ° F. 0.0011
per ° C. 0.0019

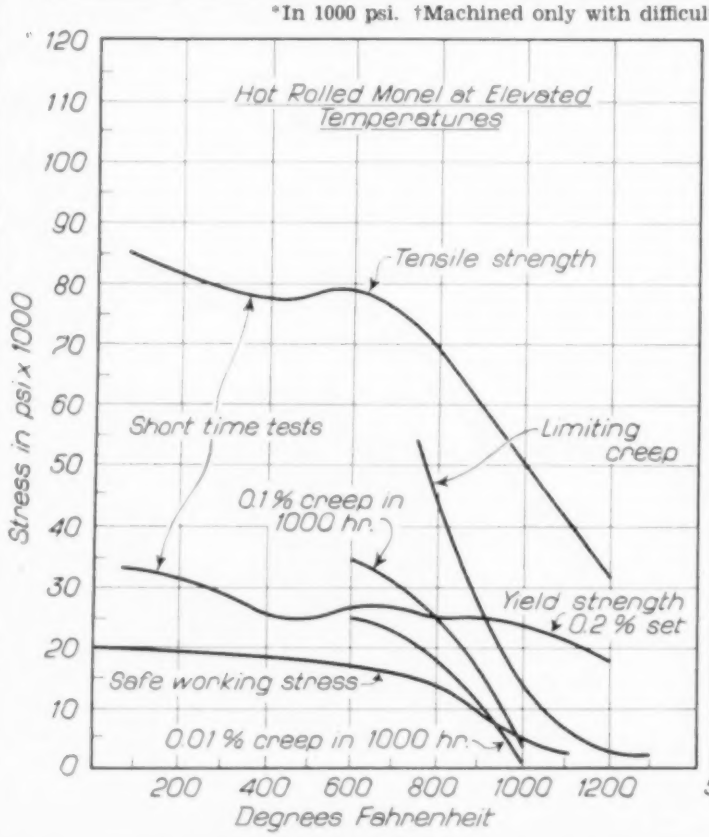
Modulus of elasticity
in tension, psi. 26,000,000
in torsion, psi. 9,500,000

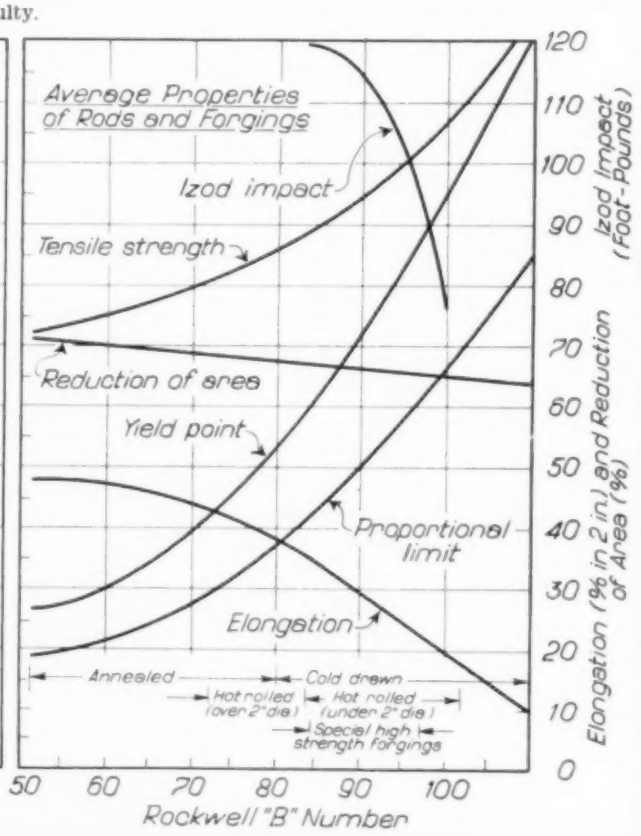
Poisson's ratio 0.32

Mechanical Properties of K Monel

CONDITION	ULTIMATE*	YIELD (0.5% SET)*	ELONGATION	REDUCTION	BRINELL
Soft, quenched from 1450° F.	<120	<80	>40	>50	<225
Reheated to 1000° F.	120 to 140	80 to 100	>30	>35	225 to 275
Reheated to 1100° F.	140 to 160	100 to 120	>20	>25	275 to 325
Cold worked and reheated to 1100° F.	>160	>120	>15	>20	>325†

*In 1000 psi. †Machined only with difficulty.





Institute shows the physical properties of 24-12, 60-15, and 35-15 as-cast and at room temperature. Note that on the basis of straight *cold* physical properties it would appear that a high chromium, low nickel alloy such as 24-12 is superior both in respect to strength and ductility to the two high nickel, lower chromium alloys. The second portion of the table shows the physical properties (tested at room temperature) of these same three alloys after holding at 1600° F. for about 48 hr., a very minimum of high temperature exposure. It is obvious that as soon as the high chromium, low nickel material has been subjected to even a slight amount of high temperature exposure the superior ductility disappears and it no longer possesses the advantage in toughness manifested by the properties as-cast. As practically all heat resisting alloy castings fail by cracking, it is obvious that *sustained ductility,* as indicated by sustained elongation and reduction of area after repeated heating and cooling, is a fair index of life under intermittent heating.

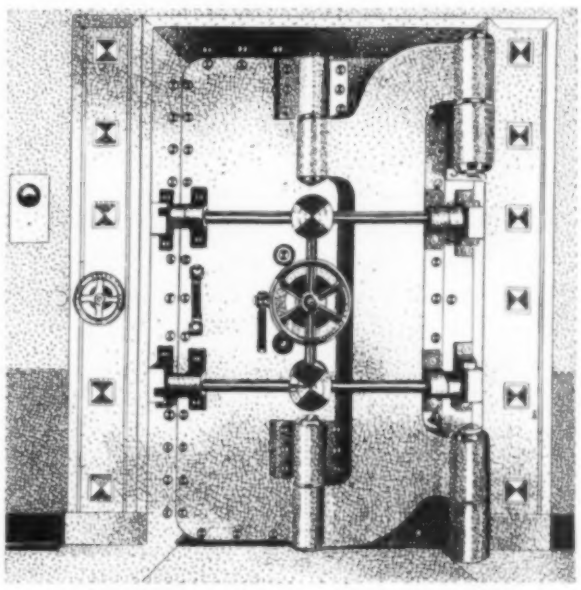
It was only a little while ago that I heard a rather well-known research metallurgist, but a newcomer to this field, wonder why anybody should use high nickel, low chromium material like 60-15 when the physical properties of 24-12 "are so much better". He was, of course, basing his observation on the cold physical properties.

The lower portion of the table shows the short-time tensile properties of castings when pulled at 1800° F. It is most significant that we then find the high nickel materials showing values in tensile strength, proportional limit and yield strength, entirely comparable with those of the 24-12 material in column one, but both of these alloys possess values, with respect to elongation and reduction of area, which are outstandingly superior. It is further well known that over long periods of service their basic strength-carrying capacity, together with their elongation and reduction as measures of their ability to resist shock, are preserved, whereas there is a gradual decline in the corresponding values of the 24% chromium, 12% nickel material. The metallurgical reason for this is that the higher nickel analyses are microstructurally more stable, and precipitate carbides from the matrix at a very slow rate.

These data, from the investigations of the Alloy Casting Research Institute, merely confirm what has long been known by the well-informed. The temptation to economize in first cost has led many to use chromium-nickel alloys where nickel-chromium is manifestly superior, or to use too low an alloy content when the latter family is chosen. The 38 Ni, 18 Cr alloy, for example, returns its average of 3¢ per lb. additional cost over 35 Ni, 15 Cr many times over. In this connection it is well to repeat what was said in these pages a year ago:

Up to about 35% nickel, 15% chromium, however, the alloys are subject to microstructural changes within the temperature ranges at which they are commonly used. Such microstructural transformations are a potent cause of trouble. The higher nickel-chromium alloys are also resistant to "heat fatigue" (breakdown due to the repeated stresses of heating and cooling) and embrittlement by carbon penetration. Since almost all failures of alloy parts come from heat fatigue rather than from uniform exposure, the practical criterion for evaluating them should be "How long will the material withstand intermittent heating and cooling without cracking?" The stresses imposed on most alloy by contact of cold charges on hot alloy parts, effect of irregular temperatures in the furnace and variable sections in the same piece — all of these add to a far greater total in most instances than the stresses produced by the load which is carried.

Principal improvements in alloys, achieved during the last year, come from refinements in secondary alloying ingredients for specific resistance characteristics — hot bearings for example. Recent introduction of much more specialized alloy engineering and design technique tending to higher mechanization of furnaces, including high temperature roller bearings, gearing, and similar elements, is making obsolete most mechanical furnaces and carburizing containers for compound or gas.



Heating Element Materials

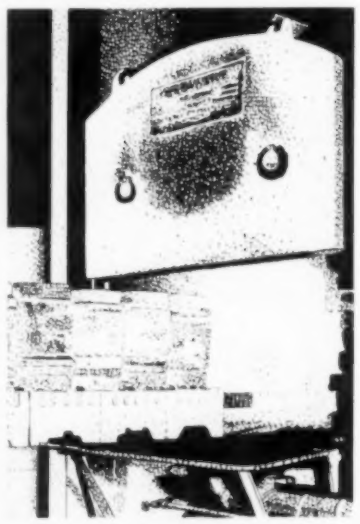
By F. E. Bash
Manager, Technical Dept.
Driver-Harris Co., Harrison, N. J.

80-20 NICKEL-CHROMIUM is still the outstanding material for use in heating elements where resistance to oxidation at high temperatures and general mechanical durability is desired.

Creep tests made during the last year on this alloy at 2000° F. indicate that a stress of 200 psi. caused a creep of 1% in 10,000 hr. This verifies the general experience of furnace designers who have used this figure in their calculations, a figure formerly based upon results which have been obtained in the field.

Since it is only through the development of tests which may reproduce conditions met with in industry that ways can be worked out for improving materials or solving difficulties, cooperative work is constantly being done through committees of the American Society for Testing Materials to work out test methods.

The life test is still being used as a yardstick for control. In future development of electrical heating materials it will continue to be used, as it has been found to be a very useful tool. It must be remembered, however, that this test only measures the resistance to oxidation; other factors are encountered in the practical application of the alloy. An example in point is the use of heating elements in furnaces, where the atmospheres are not oxidizing — as for example, in brazing furnaces, where the atmosphere is produced and maintained by the use of partially burned city gas or natural gas. Tests are under development which will attempt to reproduce atmospheres as well as temperature conditions occurring in furnaces of this sort; such a test may, of course, be used to determine the gas analyses that may give the best life of the resistor.



Work has also been done this year and a program is laid out for more laboratory work to determine the effects of various ceramics and other materials that may come in contact with heating elements.

In view of the greater durability and life at high temperatures of the improved 80-20 wire and ribbon that is now available, the tendency is to design and operate at higher watt densities; this results in greater efficiency. The future trend is certainly in this direction.

new requirements for
High Nickel Alloys

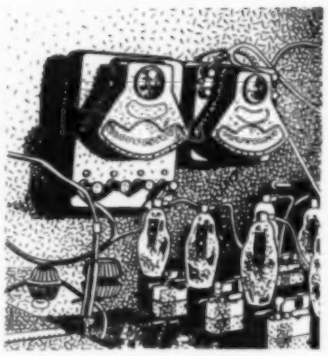
By E. C. Badeau
International Nickel Co., New York City

USES of Monel, nickel and Inconel are daily being expanded to meet the requirements of new trends, new applications and even new industries. Among the most interesting possibilities in the last group is television. This latest development in the science of communication has been a commercial reality for less than six months. Yet, already, it has shown marked progress. Within the past few weeks technical improvements have been such as to make possible the successful telecast of a baseball game. As the new industry begins to hit its stride much of the early doubt with which it was surrounded in the public mind has begun to disappear. Sales of television sets definitely have started to mount.

Since each television set contains from 16 to more than 30 tubes — many of them entirely dependent for satisfactory operation upon metal parts of pure nickel, they hold no small prospect for the nickel industry.

Transportation for years has formed one of the major outlets for nickel and nickel alloys. While the bulk of consumption by railroads, airplane, motorcar, and shipbuilders has been in the form of nickel irons and steels, a growing use is being made of rolled nickel and high nickel alloys of special characteristics such as Monel and Inconel.

Everything seems to point to larger and faster airplanes for overland as well as transoceanic service. Examples are found in the new clipper ships as well as the new DC-4 Douglas land planes ordered by United Airlines. Exhaust manifolds and cabin heaters for these



planes are made of Inconel because of its resistance to hot, corrosive exhaust gases whose natural enmity to metals is increased by higher and higher engine horsepowers. Each of the clipper ships flying the Atlantic or the Pacific uses about 1200 lb. of Inconel.

On board ship new uses for Monel have been developed, which, with the increased activity in American shipyards, will require thousands of pounds of this alloy. Among these uses are refrigerator linings, for which Monel has proved especially adapted.

Newer materials such as "K" Monel, a heat treatable alloy with mechanical properties rarely obtained in a non-ferrous material, are likewise apt to benefit from increased shipbuilding. "K" Monel has many uses from pump shafts and sleeves to valve disks and stems in high temperature steam lines.

A recently developed use which also holds promise is for corrosion resistant bearings of ball or roller types.

From the marine field comes another development that promises additional tonnage in that field, in other fields of transportation and in industrial plants. This is the use of nickel for bin and container linings of all kinds, especially for the handling of rayon quality caustic soda. This development was given impetus within recent months by the use of 60,000 lb. of nickel for lining the holds of a cargo boat. Plans are already underway for the lining of tank cars and storage tanks. Lined tanks in the form of nickel-clad steel, of course, are generally used in a variety of chemical and food industries.

New achievements in fabrication are being noted. At the New York World's Fair a pure nickel tube 0.026 in. in diameter is on display. This is believed to be the smallest metal tube ever produced and its manufacturers are discussing the production of an even smaller size, though as yet such tubes have little or no commercial use. They illustrate, however, the extent to which modern fabrication methods have progressed.

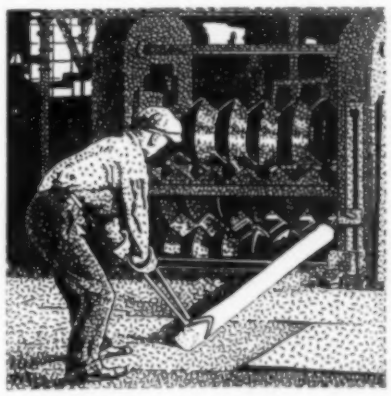
Even the modern brewery may be transformed by replacing historic materials with white metals. Forerunner of such a possibility is found in Canada where a Sudbury firm thoroughly renovated its plant and installed brewing kettles and other equipment of nickel and nickel-clad steel. Pipe lines of nickel were also used. Where it was found more expedient to make certain ornamental and other castings out of brass, they were nickel plated before installation.

Another alloy, which like "K" Monel combines the corrosion resistance of nickel and high nickel alloys with the mechanical properties of the higher strength ferrous alloys, is "Z" Nickel. Like "K" Monel, it can be heat treated. Since it is an alloy of relatively recent development, its full possibilities have not completely been explored. It has been found highly useful for springs and other small parts, particularly in electrical equipment. Many possibilities will be realized within the next year.

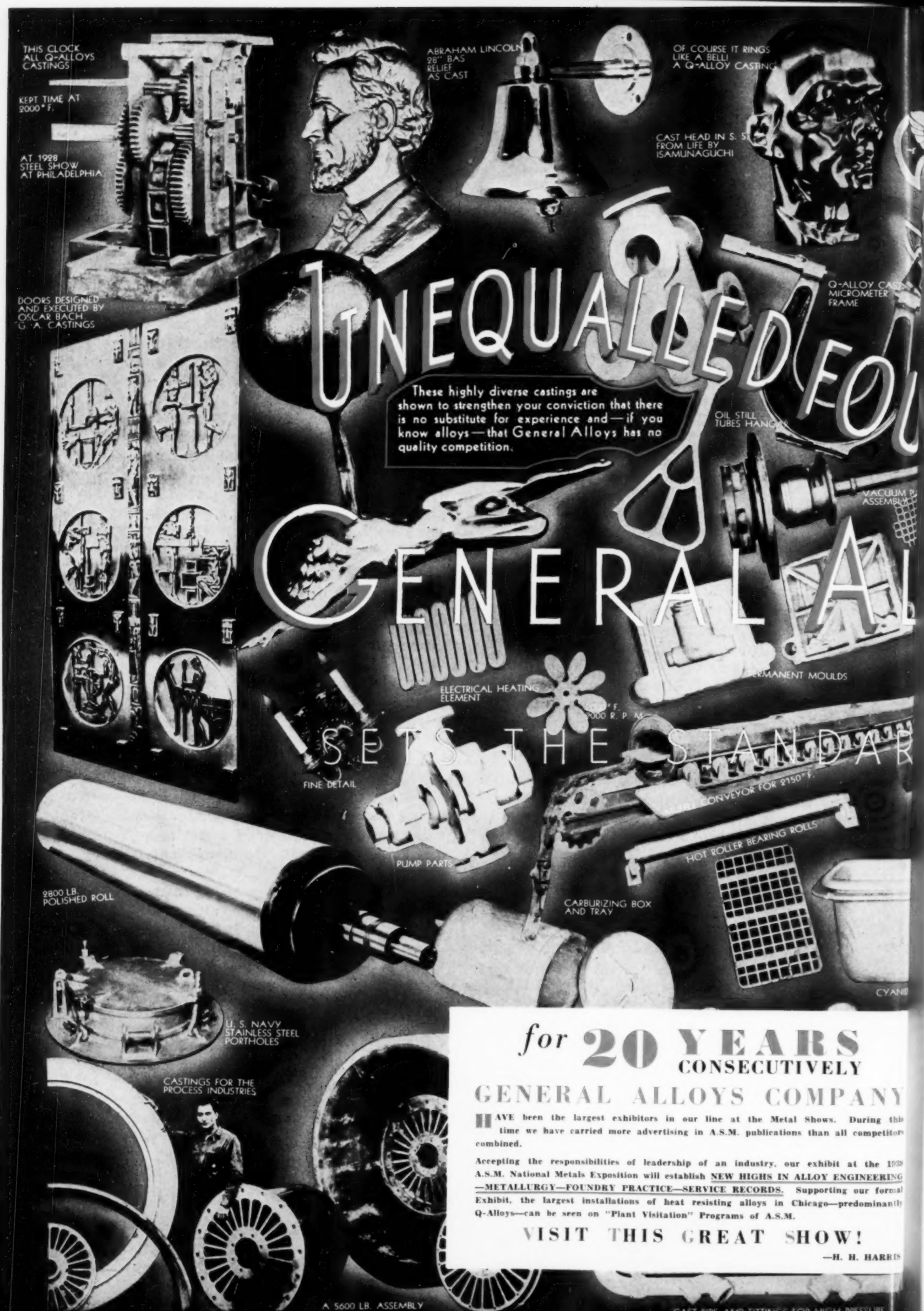
The increasing use of plastics of all kinds presents an exceptional range of opportunities since pure nickel is essential for many items of storage and processing equipment. As indicated above, the production of rayon, with its need for caustic soda free from harmful metallic contamination, continues to increase its demands for nickel and nickel-clad steel.

A growing use of clad materials, incidentally, has been noted. Included are both Inconel-clad and nickel-clad steel plate, and rolls of a variety of materials covered with nickel, Monel and Inconel sheet.

Various government projects — planned or now under construction — will account for some large tonnages in this group of nickel alloys. Outstanding among these is the new Fort Peck Dam, being built by the U.S. Army engineers for flood control and navigation on the Missouri and Mississippi Rivers. The huge valve gates — almost 30 ft. in diameter — are equipped with valve seats of heavy Monel forgings.



Almost the entire roll of industry could be called in this fashion, and almost the entire list would reveal some important development in which some product of the nickel industry will make an important contribution.


THIS CLOCK ALL Q-ALLOYS CASTINGS
KEPT TIME AT 2000° F.
AT 1928 STEEL SHOW AT PHILADELPHIA
ABRAHAM LINCOLN 28" BAS RELIEF AS CAST
OF COURSE IT RINGS LIKE A BELL! A Q-ALLOY CASTING
CAST HEAD IN S. S. FROM LIFE BY ISAMUNAGUCHI
DOORS DESIGNED AND EXECUTED BY OSCAR BACH G-A CASTINGS
UNEQUALLED EQU
These highly diverse castings are shown to strengthen your conviction that there is no substitute for experience and—if you know alloys—that General Alloys has no quality competition.
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OIL STILL TUBES HANG
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ELECTRICAL HEATING ELEMENT
PERMANENT MOULDS
SETS THE STANDAR
FINE DETAIL
PUMP PARTS
MESH CONVEYOR FOR 2150° F.
HOT ROLLER BEARING ROLLS
2800 LB. POLISHED ROLL
CARBURIZING BOX AND TRAY
CYANI
U. S. NAVY STAINLESS STEEL PORTHOLES
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WELDING AND CUTTING

METAL PROGRESS

OCTOBER 1939

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Welding and Cutting

Flash Welding

By Robert E. Kinkead
Consulting Engineer, Welding; Cleveland, Ohio

A RECENT DEVELOPMENT in high speed welding operation in a modern strip mill has been carried out jointly by the United Engineering & Foundry Co. and the Federal Welder & Machine Co. This is an automatic flash welding machine installed ahead of the pickling line. It works as follows: Hot-rolled strip steel in coils is delivered to the uncoiler ahead of the pickling line. Several turns are uncoiled and the end sheared and welded to the squared end of a preceding coil. Steel is thereupon delivered into the pit ahead of the pickling vats as a continuous ribbon. On the delivery end of the pickling vats some welds are cut out, but only to give a size of coil which can be handled with existing equipment.

The welding machine itself is fully automatic from the time the signal "All clear to weld" is given on the control panel until the weld is made, stripped, side clipped, and picked up by the pinch rolls to be delivered into the pit.

In operation the abutting ends of the two coils are first sheared square in an up-cut shear, then clamped in the welder clamps, again sheared by a rotary shear which goes between the welder clamps. The welding cycle is then carried out and a hydraulic gripper pulls the strip through a V-shaped plow to strip any flash. When this operation stops the weld is in the right position to have the side clippers remove the uneven ends of the weld.

This equipment gives more output per pickle line. It produces soft welds which will go through the cold mills without failure and be rolled down without causing a perceptible "bump" in the mill.

Electric Arc Welding

By Louis J. Larson
Consulting Welding Engineer
Milwaukee, Wis.

THE USE OF WELDING as a method of fabrication continues to increase. Each year finds new companies adopting welding for some of their products and former users of the process increasing their amount of welding. Castings are being replaced by fabricated structures and rivets are being replaced by welds. Gradually, also, engineers who have not trusted welding for some of their structures are being educated and convinced that the process is reliable when used under proper supervision.

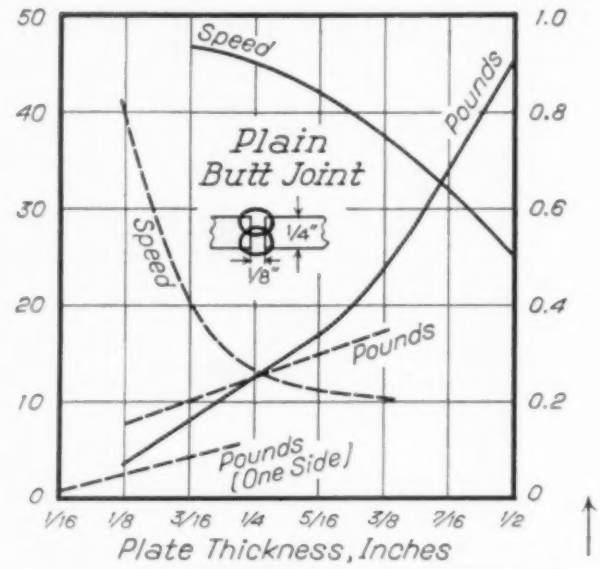
In the development of equipment one of the chief objectives is an improvement in the welding characteristics, particularly in the low amperage range. Machines are being simplified in construction and weak points eliminated to reduce maintenance costs. Furthermore the price has been materially reduced. A new tube rectifier has been developed which operates satisfactorily at very low current, 10 amperes or less. This will result in many applications to light gage material, for which arc welding was formerly impractical.

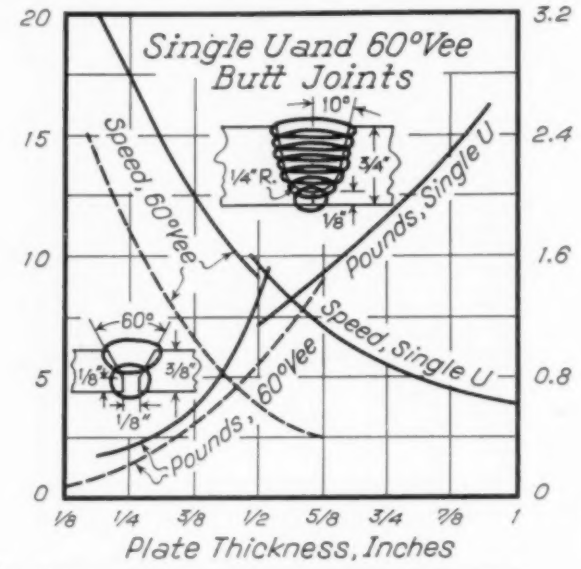
In the manufacture of electrodes an effort is being made to increase uniformity. This is no simple task. It often requires a considerable investigation to determine the causes of variations in behavior. Numerous specialized electrodes now accomplish certain results, such as increased speed, smoother finish, less spatter, better operation with alternating current. In some cases these results are attained by modifying old types and in other cases by developing new ones. Efforts to obtain the shielded arc action with a continuous electrode continue.

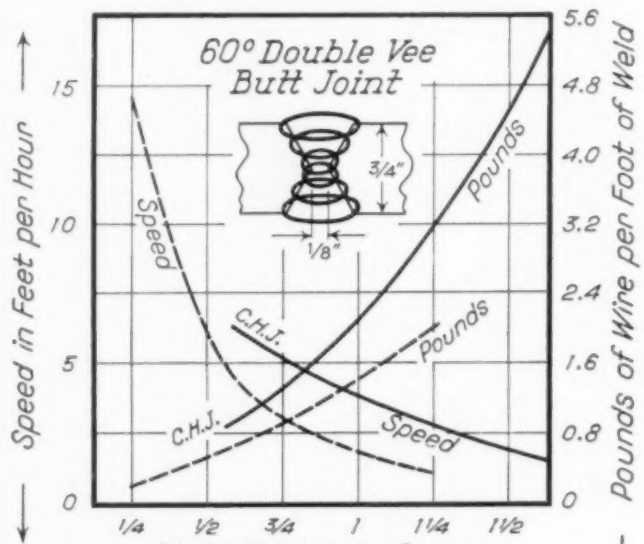
Speed of Manual Arc Welding

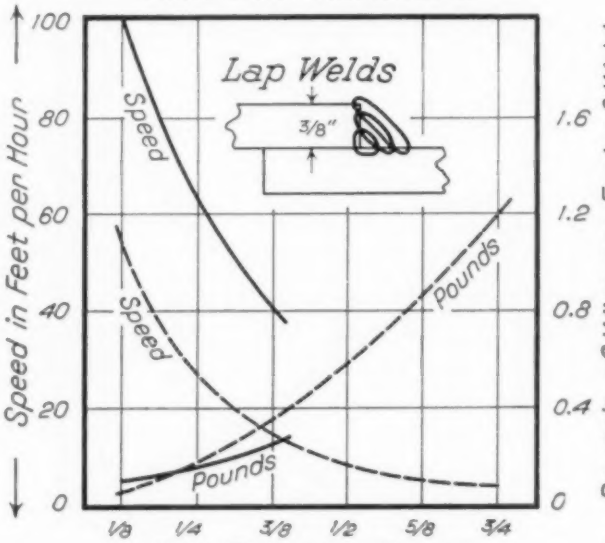
In down position and 100% operation factor. Discount speeds according to efficiency of shop management up to 50% for piece work and 67% for day work

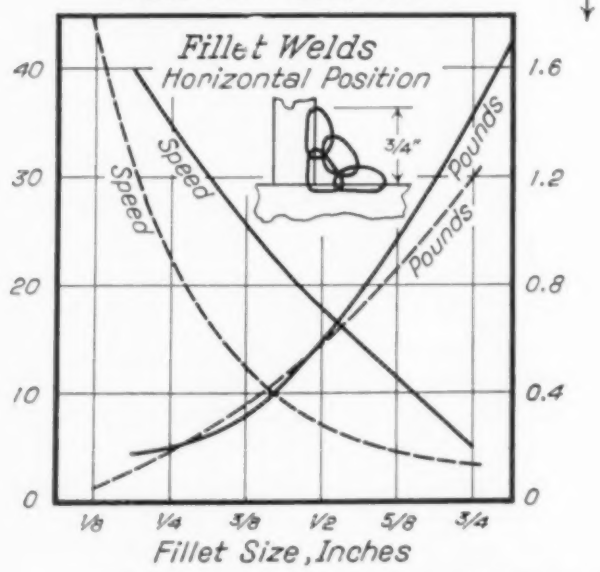
——— Coated Electrode or Shielded Arc ——— Bare, Washed or Dusted Electrode

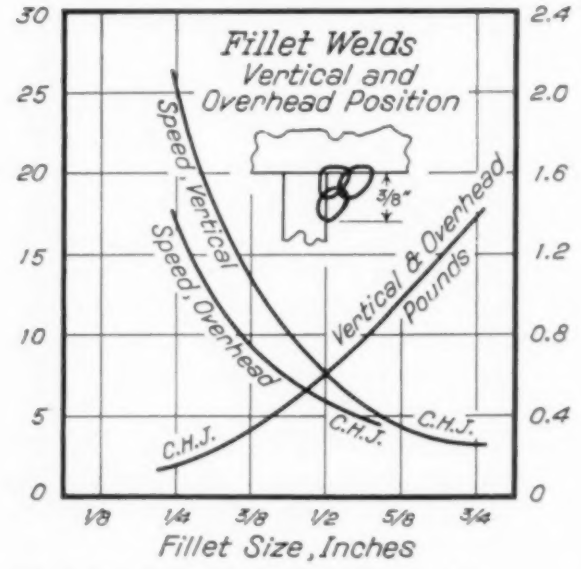












Data from "Procedure Handbook of Arc Welding", Lincoln Electric Co., except curves marked C.H.J. from "How to Weld 29 Metals" by Charles H. Jennings, Westinghouse Elec. & Mfg. Co.

For certain applications the use of coating material in the form of tape which is progressively formed around the steel core by the welding head has produced excellent results.

Atomic hydrogen welding, which has some characteristics of both arc and gas, has found increased application in the last year or two. The quality of the joints made with this process has always been excellent, but for all except light gage or special material it has been considered too expensive. It has now been demonstrated that by the use of multiple arcs the process can compete successfully, on a cost basis, with metallic arc welding even on medium heavy plates. However, considerable equipment is required and the process is therefore limited to mass production.

From the standpoint of the user, more accurate quantitative data on both equipment and electrodes are desirable. New models of welding machines are brought out from time to time and the user must decide whether it is more economical to trade in his old equipment or to continue using it. Obviously if his old equipment will not satisfactorily do the work required, or if maintenance is excessive, it should be replaced. But if the old machines are doing satisfactory work, should they be replaced because of the increased electrical and welding efficiencies of the new? Data on the relative efficiencies are lacking, and difficult to obtain in the average shop.

When buying new equipment the user must decide between alternating and direct current. For certain purposes direct current is alone suitable; for others alternating current; but in many instances either type can be used. The choice then depends upon a number of factors, among which are the relative power costs and the welding efficiency of each type. Most data on these factors are too general to be of value in specific decisions.

More data on the mechanical properties of weld metal made with various types of electrodes would be helpful to the user. Properties are affected to a greater or less degree by stress relieving and by annealing. Although some electrodes are used primarily on structures which are stress relieved, and others on structures which are not heat treated, both types may be used on the same structure. It is therefore desirable to know the properties of welds after various heat treatments.

The conditions under which the welds are made may also affect their properties. Size of electrodes, welding amperage and voltage, and temperature of the work influence the deposited metal, more or less depending upon the type of electrode. Some specifications for weld rods permit, or even stipulate, welding conditions which differ greatly from those under which the electrodes are actually used. If the effect of changes in welding conditions were the same for all types of electrodes, comparative values would be obtained when all types of electrodes were tested under the same conditions. Unfortunately this is not the case, and it is therefore important to know the properties after welding under the actual conditions in production.

The welding industry as a whole would benefit greatly by the standardization of codes, particularly the sections which govern qualification tests. Even though a manufacturer has qualified his process and operators for work under one code, he may be required to re-qualify before starting similar work covered by another code. If all the code-making bodies adopted the same procedure for testing each type of weld it would save the manufacturers both time and money. Any unnecessary expense increases the cost and retards the acceptance of welded machinery and structures.

Resistance Welding

By E. W. Forkner
Chief Engineer
The Federal Machine & Welder Co., Warren, Ohio

FOR A NUMBER OF YEARS, following the introduction of spot welding, progress was marked by the pronounced trend to speed up welding operations. As a result of constant effort expended toward this end, present-day multiple point machines, of the ultra-speed type, provide facilities for making as many as one thousand spot welds per minute. Time and thought given to gaining greater speed, together with the delay necessary for development of new metals and alloys, contributed to retard a rapid change in welding technique; however

this change was expedited, in a great degree, by concerted effort on the part of various manufacturers of precision devices for current control. Prior to the advent of precision control of electric current, materials such as aluminum, stainless steel or high zinc alloys were considered not well adapted to welding.

During long current dwell on the latter mentioned alloy, the zinc had a tendency to gasify during the heat period, which greatly impaired the strength of the weld. Today, with adequate current available, and through the use of short precision timing, we join such materials with no question as to quality of the operation.

The limited heat range of aluminum alloys presents a similar problem, so far as accurate control of current is concerned. Stainless steel, most of which has been through a cold working process, requires definite control of current in order to confine the heat to the weld zone.

The foregoing relative to technique, being definitely established at present as good practice, opens an unlimited field to future industry. We may point to one example where resistance welding is being used (in a limited manner at present) in the production of some component assemblies by various leading producers of aircraft. This certainly indicates a bright future for further development in the welding field. Fabrication of entire wing, fuselage and empennage sections of aircraft, by means of resistance welding, should not be regarded as distant.

In keeping with progress made in the spot welding of numerous alloys, other resistance welding applications have improved accordingly. The writer refers, in this instance, to flash welding of similar and dissimilar alloys. One such example is the welding of landing gear rims of aluminum alloy. In manufacturing sequence the stock is cut to developed length and width. It is then curled in rolls to establish the correct cross section and shape. The abutting ends are then flash welded together. In this manner the diameter and cross section are maintained with reasonable accuracy.

Other methods are worthy of mention, even though not particularly new in origin, one of which is the application of resistance heating for hardening, upsetting or annealing to suit special requirements. This is usually accomplished with the use of a flash welding type of machine. Current is generally applied long enough to eliminate any necessity for a precision control of a synchronous type; however, if the operation involves a critical heat range, a photo-electric set-up may be employed. In the latter case, the work is used as the light source, and the photo-electric cell adjusted to meet the heating requirements. This type of operation points to a fairly broad field and, in addition, may offer a solution to other conventional jobs, such as hot heading, or operations of a similar nature.

In many instances, developments of today are accepted practices of tomorrow. In like manner, conventional practices of today often furnish the basic requisites for future developments.

Pipe Line Welding

By Lewis F. Scherer
Assistant Chief Engineer
The Texas Pipe Line Co., Houston, Texas

PIPE line company officials have generally been occupied during the past year with other problems than the technique of pipe line welding. These seem to have reached a satisfactory state, at the moment. In fact, through improvement of the joints it has become possible for us in the pipe line industry to use very light pipe. The tendency noticeable a couple of years ago among a few companies has now become quite general. The use of this light pipe (which is still within the safe working stresses of the pipe steel) has permitted a considerable saving in construction costs.

In view of the above, I feel, more than ever before, that there is a very definite need for the development of suitable equipment to permit rapid and accurate inspection of butt welds in pipe lines. This is a problem that must be solved in the immediate future.

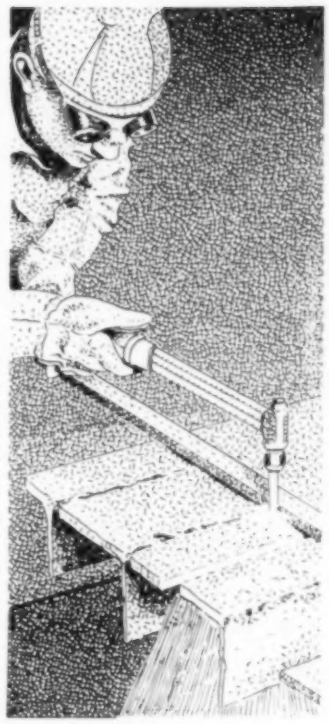
oxy-acetylene
Mechanical Welding

By Glenn O. Carter
Consulting Engineer, The Linde Air Products Co.
New York City

WHILE it is generally conceded that the current trend of development in high-speed welding is toward mechanization, it may be said that, until recently, the inherent flexibility of the oxy-acetylene flame paradoxically handicapped mechanization of the oxy-acetylene process. In other words, the oxy-acetylene flame has been used almost exclusively in hand-operated welding blowpipes where flexibility was a predominant requirement. Now, however, it is becoming more and more evident that

mechanization with the oxy-acetylene process offers very definite possibilities, particularly for many sheet metal applications.

Of considerable interest, and perhaps one of the most spectacular examples in the field of mechanization, is the recent development in tube welding. This operation has been increased as much as 300% in speed in the last few years. For example, with 20-gage material it is now possible to weld continuous tubing at a rate of 50 ft. per min., whereas a few years ago 15 ft. per min. was much better than average.



Latest developments also indicate a definite trend towards mechanization in those processes using rod or added weld metal. This is equally true with respect to both ferrous and non-ferrous metals. Among such developments, now either in commercial use or nearing commercial introduction, is the welding of steel containers, made of halves joined with a single circumferential weld. The mechanical welding of aluminum beer barrels of similar assembly also appears to be very near to commercial utilization.

Present indications also seem to reveal a very broad field for mechanization of bronze welding, using the oxy-acetylene flame in conjunction with vapor flux. This principle is applicable not only to steel, but also to non-ferrous metals such as everdur and copper, either solid or clad. Speeds ranging from 6 ft. per min. on 20-gage material to 3 ft. per min. on 11-gage material have been obtained. Material as thin as 28 gage has been joined successfully by oxy-acetylene mechanical welding at speeds of better than 10 ft. per min.

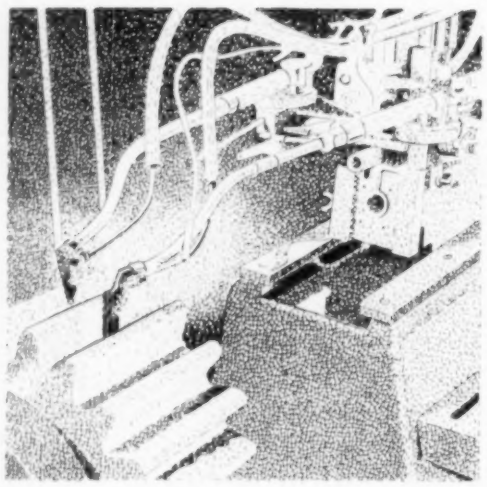
Flame Cutting

By George V. Slottman
Acting Manager, Applied Engineering Dept.
Air Reduction Sales Co., New York City

PLATE EDGE PREPARATION, the simultaneous cutting of double and triple bevels on plate edges with a single pass of the oxy-acetylene cutting machine, is an application on which shipbuilders are focusing attention. Close fit-up, tolerances in the thousandths, are presenting the oxy-acetylene industry with a real problem in precision. Striking success in solving this problem has been obtained with the use of multi-torch units, but considerable development work in the cutting technique remains to be done.

An insistent and general demand for highly accurate cutting for welded fabrication has been noted. At the present time, tolerances of less than $\frac{1}{16}$ in. in 5-ft. diameter circles are being required by some equipment manufacturers. The question of ultimate accuracy guaranteeable in machine cutting is affected by tolerances in machine construction, accuracy of the oxygen cutting jet, and to a considerable extent, by movement of the piece from heat generated at the cut edge. Machine inaccuracies can be reduced below any reasonable required tolerance at a cost, since machine accuracy depends largely on the quality built into the machine. The accuracy of the cutting jet, particularly on thin plate, is largely a matter of cutting tip maintenance. On heavy sections, however, there is undoubtedly room for improvement in tip forms. Movement of the piece being cut, the major cause of inaccuracy in machine cutting large sections, has received much study both in the plant and the laboratory. The ultimate goal of machine cutting is to obtain accuracies approaching fine machining.

Flame machining still remains the most interesting commercially dormant application of the oxygen cutting principle. Why this should be so in view of the fact that apparatus for this process and a developed technique have long been available is difficult to discern, particularly in view of the universal adoption of the flame machining principle in the surface conditioning of huge tonnages of raw steel for the finishing mills. The choice of rough machining tools versus flame machining is the choice of high initial investment and low operating cost for the machine tool against smaller capital investment and higher operating cost of flame machining; it is affected also by the reluctance of well tooled industries to allow such equipment to stand idle. Flame machining is certainly one of the operations of the future, and to the future also must be consigned the ques-



tion of where and when it will become a generally recognized tool of industry.

Viewing the past year in retrospect, the most significant thing about flame cutting was the continued application of the deseaming technique to the conditioning of high quality steels. First regarded as a method of salvaging steel stocks with surfaces too badly cracked to warrant the cost of chisel chipping, and later as a rapid and efficient method of conditioning common grades of steel, it is now recognized as capable of handling the highest quality steels. Certain precautionary treatments must be employed, such as preheating of air hardening and other thermally sensitive steels to moderate temperatures; thereupon they can be deseamed as readily and cheaply as the common steels.

Active studies still in progress along these lines lend emphasis to the relative youth of the oxy-acetylene cutting process, and to the many new uses still to be developed before it can be thought of as having reached maturity.

Differential Hardening
by the oxy-acetylene flame

By A. B. Kinzel
Chief Metallurgist
Union Carbide & Carbon Research Laboratories

THE PAST YEAR has witnessed the transition of the flame hardening process from a novel surface hardening method which offered attractive possibilities to a precision process for heat treating surfaces — both in production and in maintenance. The growth and widespread acceptance of the process is a repetition of the normal progress of a new tool of industry possessing unique and unusual properties.

Today the metal products purchaser, whether buying a small valve stem or a large power shovel, demands a long lived, wear resisting article. Flame hardening enables the designer to combine requisite surface hardness with desired core properties through the proper application of the oxy-acetylene flame to parts in final stages of manufacture. Flexibility of the process with correlative ability to harden that portion, and only that portion, of a member to be subjected to wear is an important phase of the development. Another important phase is the ability to provide predetermined depth of hardness which may be well in excess of that commercially obtainable by other methods of casehardening. The ability to control distortion within narrow limits is still another factor. Experience with the application of the process has now reached the stage where new applications may be practically resolved to combinations of older applications with assurance of consistent quality production.

The following flame hardened articles illustrate the wide field of application and perhaps suggest many other objects which may be improved by the process: Machine tool ways, gears and sprockets of all shapes and sizes, oil well tool joints, engine valve stems, pump liners, piston rods, cams, ice skates, hog knives, rolls of all kinds, spindles, drill bits, wrenches, plug valves, shafts, shear blades, rail ends, crankshaft bearings, crane wheels, link pins, tractor rollers.

It is generally agreed that the flame hardening process is destined to become increasingly important because it is unhampered by many of the restrictions placed on older methods. It is simple, flexible, inexpensive, and can be applied to a large number of common steels, to cast iron and malleable iron, as well as to carburized articles.

Hard Surfacing

By Charles H. Shapiro
Metallurgist, Reed Roller Bit Co., Houston, Texas

HARD SURFACING, referred to also as "hard-facing", is the process of protecting or prolonging the life of a surface by depositing thereon a hard wear resisting alloy. The chief characteristic of hard surfacing materials is their ability to attain a high degree of hardness on deposition without further heat treatment.

Hard surfacing is no longer limited to the reclaiming of old worn parts, but is being applied to an increasing number of new parts before their first use. Each day sees a greater and wider adaptation. The result therefrom is increased life when applied to new parts, economical method of salvaging and rebuilding of worn parts, and an over-all increase in the general operating efficiency of the part itself.

Deposition of the abrasion resistant, hard surfacing materials can be either by the electric

or acetylene process. The procedure used in the fusion of "hard-metals" varies somewhat according to the tool being surfaced. Since economy and efficiency are directly controlled by the application method, much study has been given to this point. The main problems encountered are *(a)* alloying of the hard-surfacing with the base metal, *(b)* proper method of attachment of the hard-metal with the base metal, and *(c)* grinding and preparation of the finished surface.

Materials for hard surfacing fall into three general classifications: 1. Alloys with a ferrous base. 2. Non-ferrous alloys. 3. "Hard carbide, diamond substitutes."

The first class of materials finds a widespread and general use where a high order of hardness and abrasion resistance is not necessary but where impact loads are quite severe. These ferrous alloys are very often used in the rebuilding of a part to size and act as a base as well as a binder metal for the harder surfacing materials. The second class is one in which most metallurgists have some knowledge. It is the type represented by the well known chromium-tungsten-cobalt family of alloys and others with similar properties. The third classification is that of "diamond substitutes" such as tungsten and boron carbides.

New application methods are continually being developed, especially for the diamond substitutes. The newest of these is that of "sweating-on". Metal so applied is found to be uniformly distributed on the surface covered. By this method one can limit the amount of alloying that will take place between the hard surfacing and the base metals. The amount of hard surfacing metal used is also held to a minimum. "Sweating-on" results in a desirable combination of hardness and toughness. Carbides may be successfully "sweated-on" by the oxy-acetylene or the atomic-hydrogen welding processes.

The future will see a more widespread use of hard surfacing materials in those fields which recognize its advantages, and many uses in new fields, at present unexplored.

It may be of interest to point out that hard surfacing, in some form as applied by fusion welding, has found a number of uses in almost every production field. In the automotive industry a recent survey found more than 40 major hard surfacing applications on various tools and parts, and the number is increasing. In the steel mills of today there are records

of more than 120 noteworthy applications of hard surfacing metals, each of which increases efficiency and economy and lengthens the life of an important part. The advantages can be readily appreciated if it is considered that parts which receive a hard surfacing application show an increase in life and efficiency which varies from two to ten times that of an identical piece without it.

One can see a great future for the use of hard surfacing as applied to various war implements and equipment. Hard metals have come into use since the great War, and therefore have not as yet had a chance to play their part, but the advantages of this material may soon be utilized to the fullest.

The writer's first experience with hard surfacing metals dates back to 1924. In the 15 years intervening, an ever increasing number of uses have been noticed. It can safely be said that hard surfacing is indispensable to the oil industry. The advances made in the drilling and petroleum producing division, to all practical purposes, date from the introduction of hard-surfacing materials. There are a number of examples in other industries in which a similar story could be told of hard surfaces resulting in economy and in the solution of vexing problems, increasing the life of various tools, eliminating shut-downs, salvaging parts, and maintaining high production rates.

There are many difficult problems in the manufacture and application of hard surfacing materials which are being given intensive study. The future will see their solution and the benefits therefrom will accrue to all industry.

Residual Stresses

By James C. Hodge
Chief Metallurgist
The Babcock & Wilcox Co., Barberton, Ohio

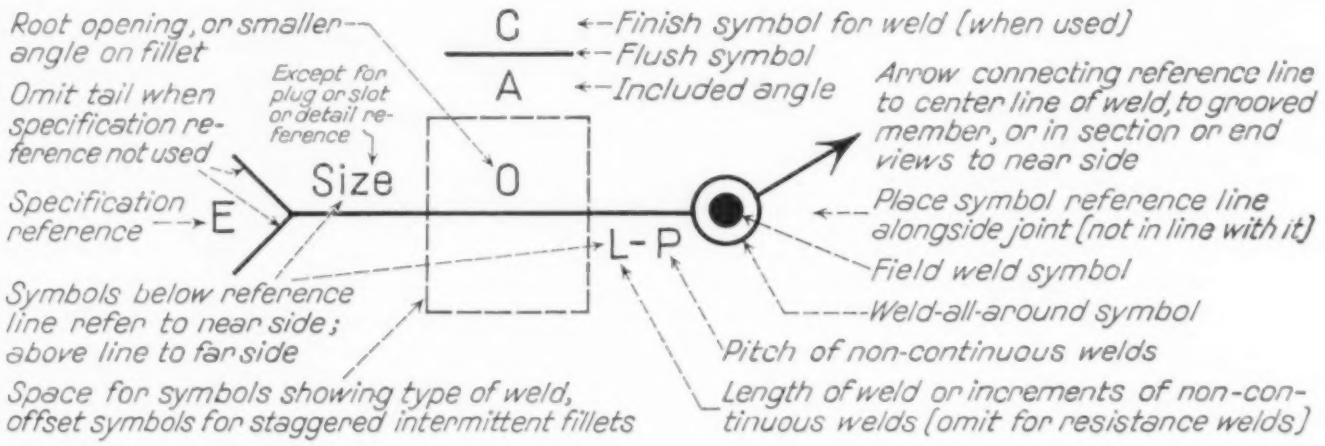
IN RECENT YEARS much investigational work has been conducted into the character, magnitude and distribution of the internal stresses resulting from fusion welding, and the internal stress patterns of the more simple types of welded joints as made by different fusion welding processes have become fairly well

Welding Symbols

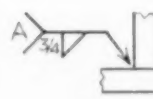
Adopted as Standard by American Welding Society, 1937

For Fusion Welding								For Both			For Resistance Welding			
Type of Weld											Type of Weld			
Bead	Fillet	Groove					Plug & Slot	Field Weld	Weld All Around	Flush	Spot	Projection	Seam	Butt
		Square	Vee	Bevel	U	J								
⌒	◺	ı	⋁	⋁	⋎	⋎	▽	●	○	—	✳	✕	XXX	ı

Standard Location of Information on Welding Symbols

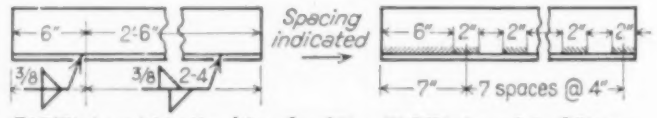

Root opening, or smaller angle on fillet
Omit tail when specification reference not used
Specification reference
E
Except for plug or slot or detail reference
Size
C
Finish symbol for weld (when used)
Flush symbol
A
Included angle
O
L-P
Arrow connecting reference line to center line of weld, to grooved member, or in section or end views to near side
Place symbol reference line alongside joint (not in line with it)
Field weld symbol
Weld-all-around symbol
Pitch of non-continuous welds
Length of weld or increments of non-continuous welds (omit for resistance welds)
Symbols below reference line refer to near side; above line to far side
Space for symbols showing type of weld, offset symbols for staggered intermittent fillets

Significance of Typical Combinations



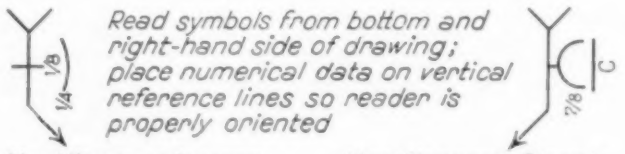
Indicates continuous ¾" fillet weld on near side, made under shop's own specification A,

Significance: Weld all around (encircling member as far as possible). Near side: ½" fillet, 2" long, 5" on centers. Far side: plate has ¾" J groove (shop's standard), continuous weld



⅜" fillet weld both sides for 6". Welds on both sides are same size unless noted

⅜" fillet welds 2" long, 4" on centers, opposite sides staggered

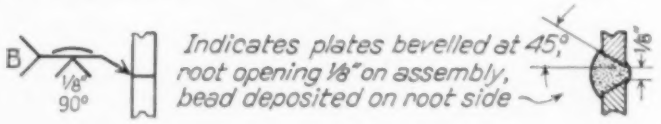


Read symbols from bottom and right-hand side of drawing; place numerical data on vertical reference lines so reader is properly oriented

Significance: Square edges on plates clearing ⅛", welded from near side, ¼" penetration required

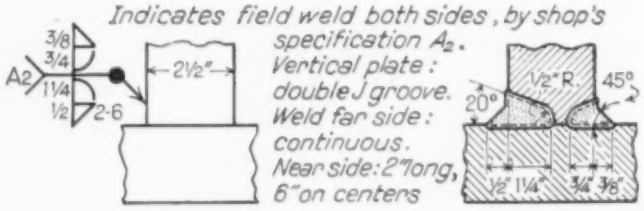
Significance: Closely abutting plates with U groove ⅞" deep, near side chipped smooth

When one member only is to be grooved arrows point to that member, thus:

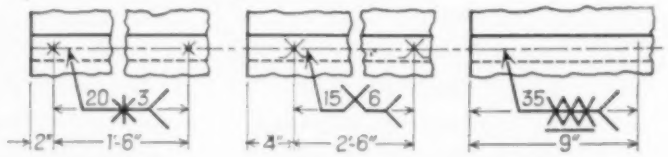


Indicates plates bevelled at 45°, root opening ⅛" on assembly, bead deposited on root side

Symbols govern to break in continuity of structure or to extent of hatching or dimension lines. Strength of resistance welds in hundreds of pounds noted instead of size:



Indicates field weld both sides, by shop's specification A_2. Vertical plate: double J groove. Weld far side: continuous. Near side: 2" long, 6" on centers



2000-lb. spot welds, @ 3" centers

1500-lb. projection welds @ 6" centers

3500-lb. seam weld, 9" long, flush near side

For other combinations see "Welding Journal", June 1937

understood. Under normal welding procedures stresses approaching the yield point of the weld or base metal have been generally found.

The effect of such residual stresses upon the serviceability of welded structures under different types of loading is not as well defined as our present knowledge of their magnitude and distribution. Unfortunately we generally lack experimental procedures to determine their effects under varying service conditions. This is due to the difficulty of correlating observations on even large laboratory models with the possible behavior of prototypes that are usually much larger. The importance of residual stresses in various kinds of welded structures can only be known from records of comparative behavior in service of structures, stress relieved versus not so relieved. Lacking such knowledge it is fortunate that the present general viewpoint with respect to the necessity of stress relieving important welded structures is conservative, so there is little likelihood of any appreciable number of failures occurring in structures not stress relieved.

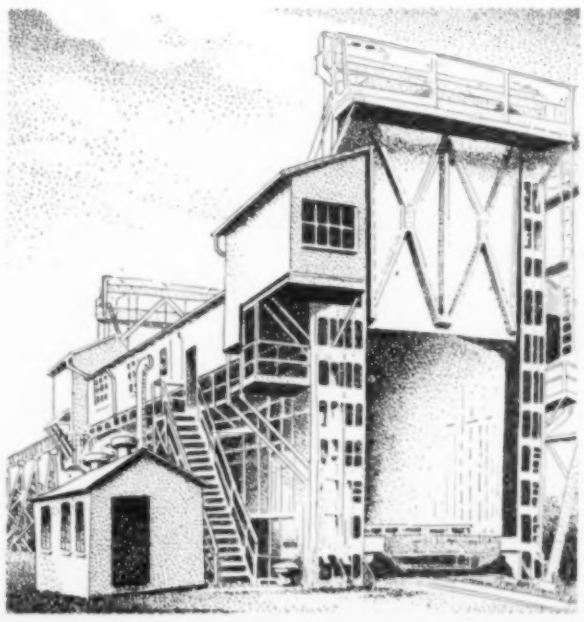
We may never have a definite answer to the question of whether it is necessary to stress relieve the complete welded structure, or whether and under what conditions it may be proper to allow local stress relieving. Numerous factors, such as material, technique, size, rigidity and intended usage, constitute a system so complicated that our present knowledge cannot be expected to fix exact limits.

As inferred from the above, the present conservative viewpoint is warranted in view of the unreliability of experimental procedures and of the lack of comparative service records of stress relieved and un-stress relieved similar structures.

No welding procedure exists whereby residual stresses may be eliminated or even appreciably diminished in magnitude, unless it be a process of welding in which the parent metal is heated to plastic temperature prior to and during welding. The latter is only a special case of thermal stress-relief simultaneous with the welding operation. Certain operations or procedures, however, may be extensively employed to *reduce* the accumulation of strain and also reduce the extent of the metal with high residual elastic stresses. These may be briefly summarized as *(a)* procedures employing the minimum amount of deposited weld metal, and *(b)* procedures involving more moderate thermal gradients and more uniform temperatures along the length of the welded joint. The latter can be most readily obtained by preheating.

Much apparatus has been built for the local stress relieving of girth joints in piping welded in the field. Efficient electrical heating units of the resistance heating or induction heating types have been developed which may also serve as preheating units.

Considerable experimental data have also been obtained relating to the efficiency of stress relieving temperatures on welds of different types of alloy steels. Further exact information, however, is necessary for determining the optimum temperature for their stress relief.



Clad Metals

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SOMETIMES it is desirable to utilize certain diverse properties of different metals by bonding them into a single unit. This may consist of nearly equal proportions (such as in utilizing differences in expansivity in building bi-metallic thermostat elements), or as a relatively thin shell or armor (as exemplified by a gold clad base metal article). Such clad metals or bi-metals, which are similarly formed, differ from coated materials in that the constituent metals are united as separately formed parts, and this union is usually followed by some additional forming operations. Coatings, of course, are normally built on a prepared base material by methods like electrodeposition, metal spraying and hot dipping.

The most common method of cladding flat products is to heat together clean sheets or slabs of the constituent metals and hot roll or press the composite to weld the adjacent faces. Usually this requires a

previous weld around the edges of the slabs, or the use of a suitable non-oxidizing gas or a flux to prevent harmful oxidation before a permanent bond is effected. Similarly, in place of welding or uniting the faces by interdiffusion, a joining material such as silver solder may be used to bond the metals. Once united, the composite slab may be hot or cold worked to desired dimensions.

Another widely used method — the oldest one — is to cast one metal around or against the face of a metal slab. Here again it is necessary to prevent oxidation at the interface. A gaseous or liquid flux is ordinarily used. Often the slab is preheated to improve the bond, and the final composite casting is rolled to size. Continuous casting of babbitt on steel strip is an important method of preparing metal for bearings.

Among the miscellaneous methods now used for special purposes the following are considered of most importance.

1. Cladding may be effected by criss-cross welding of one sheet to another, as by resistance welding or close spot welding. Fusion is localized at certain spots or strips on the interface but the bond is sufficient for many purposes.

2. Sometimes the cladding material is perforated and, after fitting it tightly to the base metal, the holes are plug welded or filled with weld metal of the cladding composition.

3. A cladding composition may be fused onto a base plate by an electric arc or by other welding means. This effects a tight bond which needs little or no further hot work but leaves a rough surface which frequently requires dressing in some manner. An example is the hard facing of steels with stellite.

Obviously, by changing the form of the materials, clad rod or wire and tubing are obtainable, although sheet, strip and plate are the most common forms of clad materials. Copper-clad steel wire, formed by the casting method and drawn to size, is an important commercial product, however, and tubing formed by drawing concentric tubes of different materials is not uncommon. Likewise, cladding may be on only one side or on both sides, or the final composite product may consist of several laminations, depending on how the original sandwich was built.

To effect a better bond an intermediate material is sometimes placed between faces of the materials to be joined. Thus, by electroplating relatively pure iron on stainless steel, high carbon steel, stellite, nickel, and the like, they are said to be more easily used as cladding materials on a mild steel base. Similarly, an intermediate layer of copper is useful in cladding silver to steel. An intermediate layer may be used to prevent excessive diffusion, also, as exemplified by the use of a thin sheet of nickel when pressing and rolling a sheet of 18-carat gold onto a planed ingot of copper or bronze.

In recent years the cladding of carbon steel with stainless steel has become of some importance, but the cost of the operation has limited the field of application. The usual method is to place two slabs of 18-8 (or other analyses up to 25% chromium, 12% nickel steel) face to face in a mold with a thin separating layer, such as calcined magnesia, lime or talc to facilitate later separation, weld tightly around the edges, and cast the backing steel around these slabs. After rolling to size the edges are trimmed and the two units separated. The stainless cladding is usually nearly one quarter of the total thickness. In making tri-clad, with a stainless layer on both sides of a steel center, difficulties in oxidation and pickling are encountered on hot rolling, which, with the additional layer of chromium-nickel steel, raises the cost at present to that of solid stainless. Other ways of cladding with stainless steel were mentioned previously under the miscellaneous methods of cladding. Clad sheets down to 18 to 20 gage and plates up to an inch and more in thickness are commercially available.

Obvious difficulties arise in welding these clad materials but with proper precautions satisfactory joints can be secured.

Aluminum clad materials, such as the well known alclad (duralumin clad with commercially pure aluminum), are important products. Considerable success has been attained abroad in making a thin cladding of aluminum on steel by roll welding.

The cladding of precious metals on base metals is comparatively old, as in making "gold filled" jewelry by silver soldering the precious metal to a copper alloy base and rolling, but the extension of these older methods to electrical contact materials, thermostat bi-metals, and the like has vastly increased the importance of this industry. Among many of the miscellaneous applications are cladding or joining bearing bronzes to steel and making stainless steel lined copper vessels. New products of clad materials are being constantly offered as difficulties in bonding and working dissimilar materials are overcome and costs are reduced.